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*C. EDGAR ALLEN.*

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**Our South American Number.**

In surveying the opportunities that have existed during recent times for the development of our commercial interests abroad, there has been a certain tendency to allow our Colonial possessions to take a place and prominence which, however largely due to them, has to a certain extent obscured the legitimate claims of other fields.

Most manufacturers have had an eye on the markets afforded by the Central and South American Republics, and the volume of British trade therewith bears witness to the fact that few opportunities for commercial development in Latin America have been allowed to slip from our grasp.

As between Great Britain, the United States and Germany, our proportion of this trade has been a preponderating one, and during the last period of ten years for which figures are available, has shown a steady increase. The same figures indicate that the other countries mentioned have not been slow to realise the value of these markets and that a state of very close rivalry has prevailed. Relatively, British exports to Latin America increased, between the years 1895 and 1905, by one third, while those of Germany and the United States have more than doubled. The necessity of our manufacturers challenging this rate of progress will be apparent when it is remembered that South and Central America are developing at a rate which merits the respect of the world. As pointed out in a recent report by the Director of the International Bureau of American Republics, a forward movement is taking place that will give these countries within the next decade a position not thought possible a few years ago, and will develop a commerce for which it is our duty to compete with every resource at our command.

The importance that has been attached to the idea that revolutions prevail all over Latin America and that, therefore, commerce and investments are insecure, has been greatly exaggerated; and, in the opinion of the authority above mentioned, the South American continent to-day is free of any serious insurrectionary movements or of indications of more civil wars.

With a view then of awakening the interests of manufacturing engineers to a renewed appreciation of the commercial possibilities of these countries, the proprietors of this journal decided to issue, some time during the present year, a special number devoted, in respect of its special articles, to the present position and requirements of the engineering and mining industries of Latin America. Satisfactory progress has been made in the preparation of this issue, and it is a source of gratification to the ENGINEERING REVIEW that this enterprise is

receiving active appreciation in a two-fold direction. On the one hand, not only have several of the Governments concerned co-operated by nominating native experts to write, but have notified their wish to have reserved a large number of copies for distribution. On the other hand, realising the unusual opportunity the issue will present from the point of view of publicity, a large number of British engineering manufacturers who have either business relations with, or intend entering in, the South and Central American field have accorded it a liberal measure of support. We anticipate that arrangements will be so far completed as to enable the announcement of the exact date of publication to be made in our next issue.

**The Vogue of the Tank Engine.**

The advisability of using tank engines for fast traffic was a question brought into prominence some three years ago as the result of a series of derailments that occurred in rapid succession at Tal y Cafn, Waterloo, and Llanelly, in each case the engine —a tank—leaving the road for no other apparent cause than that of high speed. It is probable that the types of tank engine employed at that time were not primarily designed for high speed, but so far as we are aware, it has never been shown that there is any inherent defect in the tank engine, as such, that renders it unsuitable for high speed running, and that, moreover, with a steadiness unsurpassed by a tender engine. Be that as it may, the period comprised within the last three or four years has witnessed a tank engine vogue for which modern competition is largely responsible in calling for improved timings on services eminently adapted for engines of this type, namely, runs of from 30 to 40 miles with but one or two stops. Increase in train loads has formed another factor in determining design with the result that a number of our leading companies have put into service heavy tank engines with large heating surfaces and driving wheels, culminating in Mr. Earl Marsh's design for the London, Brighton and South Coast Railway, which is illustrated and described in detail on another page.

This engine is employed in hauling loads of from 250 to 300 tons for a distance of 50¾ miles in 55 minutes, and similar work involving speeds of 60 and even 70 miles per hour is to be found on the London, Tilbury and Southend Railway between Southend and Fenchurch Street, the London and North Western Railway between Tring and Euston, and on other lines within the London suburban and manufacturing districts of the north. These instances amply demonstrate the ability of a well-designed tank engine to safely travel at high speed, and a great increase in their number may be anticipated for similar duties.

The trend of tank engine development in another direction is illustrated by the powerful locomotive—also described on another page—designed by Mr. Robinson for working in the hump yard at Wath on the Great Central Railway. This engine can exert a drawbar pull of nearly 13 tons, and can maintain this pull up to a speed of 9 or 10 miles per hour. This exceptional power capacity, which, however, is required only intermittently, has been obtained not so much by a large heating surface as by the adoption of a principle that seems to be rapidly finding favour amongst British locomotive engineers, namely, the use of multiple cylinders all working simple expansion. The uniformity of tractive effort thereby secured, particularly at starting, is a very desirable feature in passenger engines, but in the present instance the system has been adopted to reduce the tendency to slip and to ensure that the engine shall be ready to exert its maximum effort from any crank position.

**Live Steam Feed Heating.**

The unsatisfactory state of our knowledge in regard to precisely what takes place in a boiler during the process of the conversion of heat into steam has

largely been responsible for the uncertainty which has lingered in the minds of many—particularly of the older school of engineers—as to the advantages or otherwise that are to be derived by heating boiler feed water by means of live steam. The matter has not been set at rest by the trials conducted by Professor Goodman and Mr. D. R. Maclachlan, of the University of Leeds,* the result of which led these investigators to the conclusion that no increase in either the economy or efficiency of a boiler is to be had from the use of a live steam feed water heater, although there might be indirect advantages. The effect of this conclusion will certainly be to stimulate research into the field of the physics of steam raising; indeed, in the discussion of Prof. Goodman's paper at the Institution of Mechanical Engineers, the President stated that that institution was now instituting a series of researches on the transmission of heat through various metals, with which the question of live steam feed heating is intimately connected.

Our existing knowledge on the subject of transfer of heat is based upon the experiments of Sir William Anderson and Sir Frederick Bramwell, both of whom showed that the rate of heat transmission through a plate to water was very much greater when the water was boiling than when the water was cold and simply being heated to the boiling point. On this basis the paradox of live steam feed heating is explicable, for a boiler would be working at its best efficiency when no diminution in temperature was set up by the introduction of cold feed.

It was upon Anderson's figures that Mr. A. H. Gibson in his able article on the subject that appeared in a recent issue of this Journal* based his explanation of the paradox, but some doubt would now appear to be cast upon these figures by an independent series of experiments undertaken by Mr. MacLachlan. He used a brass vessel rigged up on a delicate balance and containing a certain quantity of water. Heat was applied by a "Bunsen" burner with a constant rate of gas supply, so that the reduction due to evaporation could be noted, the rising temperature being observed by a thermometer in the vessel. He thus obtained the rate of heat transmission and found that it followed the straight line law from which he drew the conclusion that the rate of heat transmission after boiling was the *same* as the rate of heat transmission before boiling.

This important deduction, made from experiments conducted under conditions more closely approximating those found in actual practice than do those of Anderson, who used a steam jacketed pan, is confirmed by another set of experiments recently made by Mr. S. B. Bilborough,† to which we shall refer in detail in another issue.

Anderson and Bramwell's results would only appear, therefore, to find their true application under conditions involving steam jacketing, and not under those ordinarily attached to steam raising. Mr. Geo. Wilkinson, of Harrogate, however, claims to have confirmed Anderson's results, using apparatus similar to that employed by Mr. MacLachlan, so that the position cannot be made clear until the Institution research has been completed and made known.

* *Cf.* ENGINEERING REVIEW, Vol. XVIII., p. 182.

* Vol. XVIII., p. 1.
† Transvaal Inst. Mech. Engrs., Feb., 1908.

# The Design and Construction of Mechanical Calculators.

*By WILLIAM J. GOUDIE, B.Sc., A.M.I.Mech.E.*

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**In the present article the author proceeds to some practical application of the rules of design of compound scalar calculators enumerated in his preceding articles. The types selected relate to problems connected with the screw propeller and speed of ships, the calculation of indicated horse power and the design of gear wheels.**

Some practical applications of the various rules of design will be given in this final article.*

It is not proposed to treat a large number of cases, but simply to consider in detail the design of the typical representatives of each of the classes indicated in the previous article. Readers who take the trouble to study the details and construct these instruments should find little difficulty with the design of others suited to their special requirements.

## APPLICATION TO SCREW PROPELLER PROBLEMS.

The quasifactorial expression connecting the pitch, revolutions and slip of a screw propeller, and the speed of the ship affords a simple exercise in the design of a single slide instrument. Writing it in the form already given,

$$P = \frac{10{,}133\ S}{R\,(100 - x)}, \text{ where}$$

$P$ = Pitch in ft., ranging from (say) 2 to 30
$S$ = Speed of ship in knots ,, ,, ,, 5 ,, 30
$R$ = Revolutions per minute ,, ,, ,, 50 ,, 500
$x$ = Per cent. slip ,, ,, ,, 5 ,, 30

Here $P$ is the dependent, and $S$ is naturally chosen as the independent variable. With the limits of slip chosen the bracketed quantity, which may be denoted by $K$, will have limits of 70 to 95. There are four elements involved and according to Rule I.,

No. of slides $= \left(\frac{n-2}{2}\right) = \left(\frac{4-2}{2}\right) = 1.$

As there are two denominator factors for the two slide edges, the scale of the factor placed on the upper edge of the slide has to be inverted (Rule II.).

The primary arrangement is first drawn without reference to the absolute constant, as shown in Fig. 22, with base scale unit = 1 in. The inverted revolution scale is placed on the upper edge of the slide, to the left of the datum line $YY$. Since the absolute constant here is a numerator one and the $R$ scale is inverted, this scale can be given a positive shift $a = 10{,}133$ (Rule VI.), which brings the four scales into correct adjustment for a solution of the equation. All the scale lengths are finally brought within the limiting length of the $P$ scale by shifting the $K$ and $R$ scales distance $b$ to the left (Rule V.) so that $K = 70$ coincides with $S = 7$, then shifting the $K$ and $S$ scales distance $c$ to the left (Rule IV.) so that $S = 5$ comes in line with $P = 2$. This latter adjustment is made on the finished calculator, Fig. 23, in order that the slide may not be drawn too far out the stock when the higher values of the $S$ scale are being used. The base scale chosen is the lower scale of a 10-in. slide rule, and the length of the stock is 12½ in. The special feature of this instrument is the substituted slip or $x$ scale, which is the function scale $K$ figured with the corresponding values of the slip $x$. This substitution enables direct readings of slip to be taken.

The direct rule of operation, in accordance with the equation as given above, may be stated thus:—Place the slip against the speed and read the pitch against the revolutions. The instrument, which should be a very useful adjunct to the sea-going engineer when figuring out the results for his "log," is really a propeller-slip calculator, and when used for this purpose the rule of operation is inverted and reads thus:—

Place the revolutions against the pitch, and read the per cent. slip against the speed.

* Previous articles appeared in Vol. XV., pp. 183, 258, 403, and Vol. XVI., p. 80.

**I.H.P. POWER CALCULATOR.**

Probably the most familiar illustration of a compound or two-slide instrument, embodying an expression of the purely factorial type, is the indicated horse power calculator, one or two varieties of which are on the market at present. As can be gathered from the previous discussion of the design rules, various combinations of the factor scales may be adopted. It is proposed here to combine the scales so that for given conditions of cylinder diameter, mean pressure, piston speed, and revolutions and stroke, the indicated horse powers developed by a double-acting and single-acting steam-engine, and a two-stroke and four-stroke gas engine can be simultaneously determined.

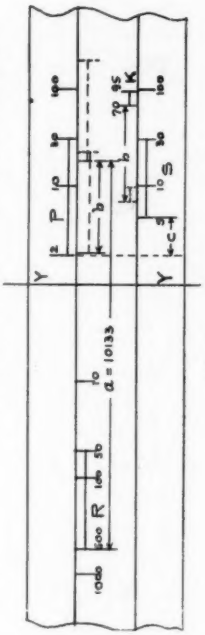



FIG. 22.

The general form of the I.H.P. equation is

$$H = \frac{Pe\ L\ D^2\ N}{C}, \text{ where}$$

$H$ = Indicated horse power, ranging from (say) ... 10 to 3,000

$Pe$ = Mean effective pressure in lbs. $\square$ ranging from (say) ... 5 ,, 150

$L$ = Stroke in ft., ranging from (say) ... ... ... ·5 to 8

$D$ = Cylinder diameter in inches, ranging from (say) ... ... ... 5 ,, 80

$N$ = Revolutions per minute, ranging from (say) ... 50 ,, 500

$C$ = A constant = 21,008 for a double-acting steam engine.

Here $H$ is the dependent and $D$ is naturally chosen as the independent variable.

There are five elements which may be varied, and hence by Rule I. No. of slides $= \left(\frac{n-2}{2}\right) + \frac{1}{2} = \left(\frac{5-2}{2}\right) + \frac{1}{2} = 2$. The $P$ $L$ and $N$ factors occur in the numerator. And if two of these scales are placed on the lower edges of the slides they require to be inverted (Rule II.). There are four slide edges for three scales, so that there is a blank edge which has to be provided with an (adjusted) index line for each case considered, to link up the combination. By choosing the upper edge of the upper slide the index lines corresponding to the fore-

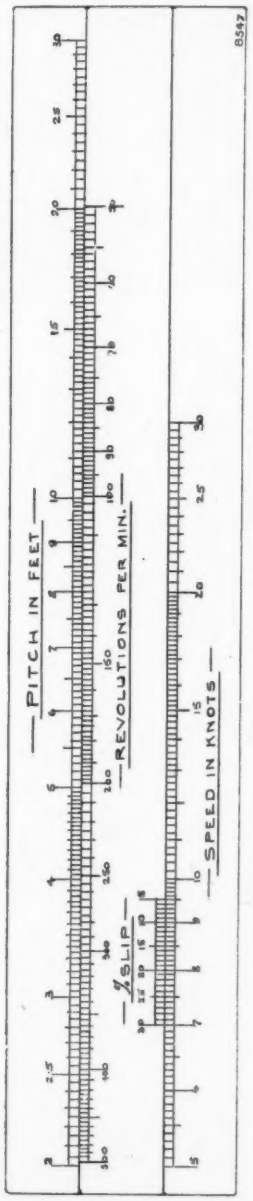



FIG. 23.—PROPELLER-SLIP CALCULATOR.

going types of engines can be placed upon it, and the four results can thus be obtained at one setting of the slides. The following is the order of the scales and index lines chosen. *D*, lower-fixed, direct; $P_e$, inverted; *L*, direct; *N*, inverted; index lines; *H*, upper-fixed, direct.

The primary arrangement of scales is first drawn without reference to the value of the absolute constant *C*, as shown in Fig. 24, the base scale unit being 1 in. The "direct" scale values are set off to the right and the "inverted" ones to the left of the datum line *Y Y*. The *D* scale unit is twice that of the base scale one (Rule III.). The adjustment of the scales to the final positions shown on the complete instrument (Fig. 25) may be carried out in several ways. The following order has been adopted here. The *N* scale length and primary index line *A* are shifted distance $x$ to the right (Rule V.) so that $N = 500$ comes in line with $L = \cdot 5$. The *N* and *L* scale lengths are then shifted distance $z$ to the right (Rule IV.) to bring $N = 500$ in line with $H = 10$. Adjustment is now made for the constant *C*. Taking the value 21,008 for the double-acting steam engine, since *C* is a denominator coefficient, and the $P_e$ scale is inverted, this scale can be shifted in the positive direction (Rule VI.) distance $k = 21{,}008$, and when this is done $P = 150$ comes in line with $D = 12$. As a final adjustment the *D* and $P_e$ scale lengths are shifted distance $y$ to the left (Rule IV.), to bring them within the limits of the *H* scale length which fixes the length of the instrument. Taking the upper scale of a 10 in. slide rule as base scale, the *H* scale length is about $12\frac{1}{2}$ in., and the instrument may be made 13 in. long. Instead of revolutions and stroke the equivalent piston speed *S* may be used in the horse power equation. The equation is $S = 2\,L\,N$. Regarding the *N* factor as the independent variable requiring a fixed scale, the *S* scale which is the other fixed scale, whether it is placed

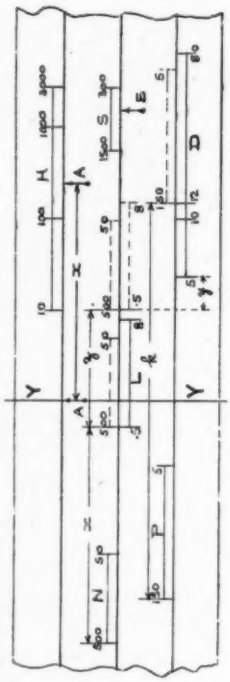



FIG. 24.

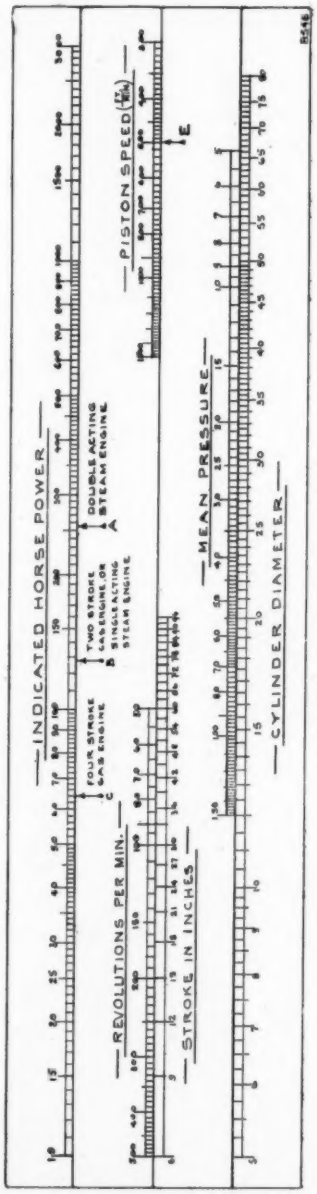



FIG. 25.—HORSE POWER CALCULATOR.

on the lower part of the stock or on the lower edge of the upper slide (fixed for the solution of this equation) will require to be inverted. This is due to the condition previously pointed out that the fixed numerator scale reads in the same direction as that of the dependent variable scale. The $S$ scale inverted has been arbitrarily placed on the upper slide to the right of the $N$ scale, with $S = 300$ in line with $H = 3{,}000$. The necessary index line $E$ linking the three scales is drawn in line with $S = 500$, which is the piston speed corresponding to pairs of coincident values on the $N$ and $L$ scales. When once the position of the index line $A$ has been fixed for the double-acting steam engine, the location of the other two index lines becomes a simple matter. For the single-acting steam engine and the two-stroke gas engine $C$ is doubled, and for the four-stroke gas engine it is quadrupled. In other words, the I.H.P. value for the double-acting steam engine has to be divided by 2 and 4. The exact location of the index line $A$ should be carefully checked by calculation. On the complete instrument (Fig. 25) $Pe = 150$ is coincident with $D = 12$, and $N = 500$ coincident with $L = \cdot 5$ ft. or 6 in. By calculation the corresponding I.H.P. for the double-acting steam engine

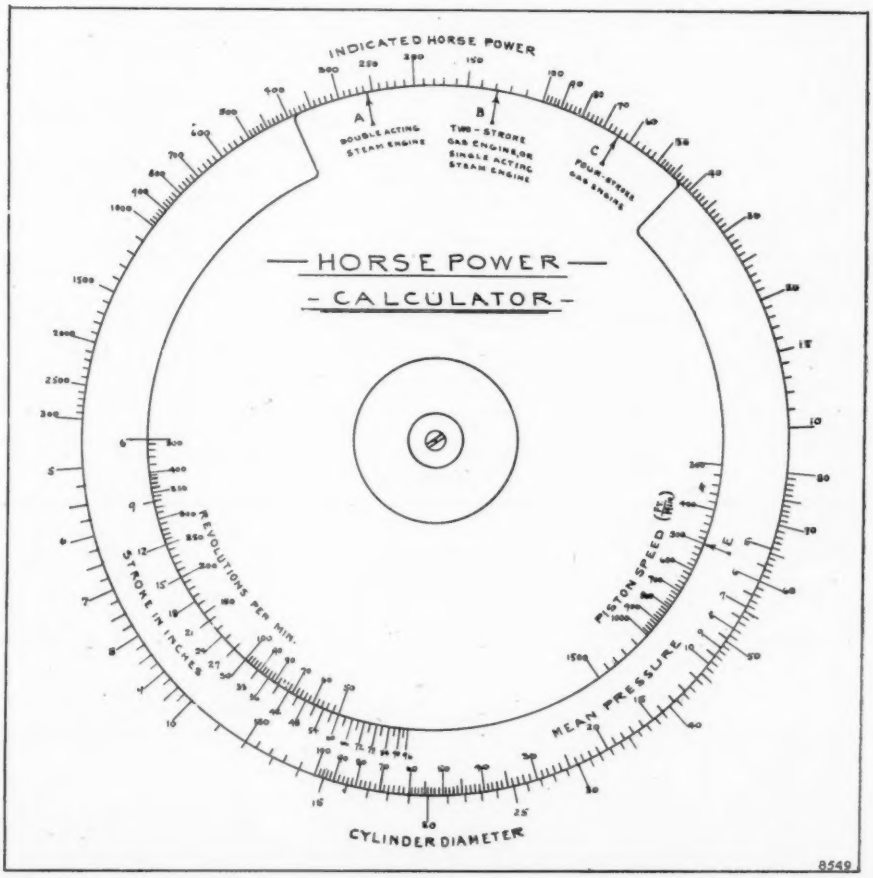



FIG. 26.

is $H = 256$. The index line $A$ is therefore drawn coincident with $H = 256$, $B$ with $H = 128$, and $C$ with $H = 64$.

The stroke values, in accordance with the usual custom, are marked in inches.

The direct rule of operation for this instrument may be stated thus: Place the mean effective pressure against the cylinder diameter, and the revolutions against the stroke, or piston speed against $E$, and read the I.H.P. against the index line corresponding to the type of engine under consideration.

The disk equivalent of this instrument is shown in Fig. 26. The base circle diameter and also that of the lower disk is 8 in., and the diameter of the upper disk is $6\frac{1}{2}$ in. The $H$ and $D$ scale lengths, taken from the straight slide instrument, are equally disposed on the upper and lower base semicircles.

The $N$, $L$, and $S$ scale lengths are likewise disposed on the lower halves of the disks, and a segment is provided on the upper half of the upper disk to take the index lines $A$, $B$, and $C$. As already pointed out in a previous article* these latter scales are first set out on the base circle and then projected radially to the inner disk circle.

## APPLICATION TO GEAR WHEEL DESIGN.

When dealing with the design of gear wheels the designer is usually concerned most with the power which the wheel will transmit, and a power-transmission calculator, based on the Lewis formula previously quoted, affords an excellent example of a "group" instrument with "substituted" scales. For this case let

$H$ = Horse power transmitted, ranging from (say) ... ... ... 1 to 300
$D$ = Diameter of wheel at pitch circle in inches, ranging from (say) ... 8 ,, 90
$p$ = Pitch of teeth in inches, ranging from (say) ... ·25 ,, 4
$n$ = Number of teeth on the wheel, ranging from (say) ... ... ... 12 ,, 300
$b$ = Breadth of tooth in inches, ranging from (say) ... ... ... 1 ,, 12
$N$ = Number of revolutions per minute, ranging from (say) ... ... 5 ,, 300
$V$ = Circumferential velocity at pitch circle, ranging from (say) ... ... 100 ,, 2,500

then,

$$V = \frac{N\,p\,n}{12} \qquad (1)$$

$$V = \frac{\pi\,D\,N}{12} \qquad (2)$$

Lewis' formula for the safe load $P$ lbs. on the tooth is $P = f_t\,b\,p\,y$, and the horse power equation is $H = \frac{P\,V}{33{,}000}$, hence substituting for $P$

$$H = \frac{f_t\,V\,b\,p\,y}{33{,}000} \qquad (3)$$

* Vol. XV., p. 406.

TABLE I.

| $V$ Velocity in $\frac{\text{ft.}}{\text{mins.}}$ | 100 | 200 | 300 | 600 | 900 | 1,200 | 1,800 | 2,400 |
|---|---|---|---|---|---|---|---|---|
| $f_t$ Stress in $\frac{\text{lbs.}}{\square''}$ ... | 8,000 | 6,000 | 4,800 | 4,000 | 3,000 | 2,400 | 2,000 | 1,700 |
| $K = f_t V$ ... ... | 800,000 | 1,200,000 | 1,440,000 | 2,400,000 | 2 700,000 | 2,880,000 | 3,600,000 | 4,080,000 |

TABLE II.

VALUES OF $y$ FOR INVOLUTE TEETH, 15 DEGS. OBLIQUITY.

| Number of Teeth. $n$. | $y$. | Number of Teeth. $n$. | $y$. | Number of Teeth. $n$. | $y$. | Number of Teeth. $n$. | $y$. |
|---|---|---|---|---|---|---|---|
| 12 | ·067 | 18 | ·083 | 27 | ·100 | 60 | ·114 |
| 13 | ·07 | 19 | ·087 | 30 | ·102 | 75 | ·116 |
| 14 | ·072 | 20 | ·090 | 34 | ·104 | 100 | ·118 |
| 15 | ·075 | 21 | ·092 | 38 | ·107 | 150 | ·120 |
| 16 | ·077 | 23 | ·094 | 43 | ·110 | 300 | ·122 |
| 17 | ·080 | 25 | ·097 | 50 | ·112 | | |

For every value of $V$ there is a corresponding value of $f_t$, and the $f_t$ and $V$ factors may therefore be replaced by $K = f_t\ V$, thus reducing the number of elements to be provided for from six to five. The $K$ scale can be figured with the corresponding $V$ values, transforming it into a substituted velocity scale. Each value of $y$ has likewise a corresponding value of $n$, and this scale can be transformed into a substituted (number of teeth) scale by figuring on the corresponding $n$ values. The co-related values of $f_t$ $V$ and $K$ are given in Table I., and those of $y$ and $n$ in Table II.

For the complete substituted $V$ scale these tabular values of $f_t$ are plotted on a $V$ base, and a fair curve is drawn through the points. The intermediate values of $f_t$ are then scaled from the curve and multiplied by the corresponding velocity values.

In dealing with this case, equation (3) is taken first. The $K$ factor is chosen as independent variable, and its scale therefore becomes the lower fixed one. The $p$ scale, in the primary arrangement shown in Fig. 27, is placed on the lower edge of the lower slide, and has to be inverted (Rule II.). The $y$ scale (direct) is placed on the upper edge of this slide.

As there are three scales for four slide edges, one of these edges has to take the necessary index line. The lower edge of the upper slide has been chosen for this purpose, leaving this edge available for the scales necessary for the solution of equations (1) and (2). The remaining $b$ scale (direct) is placed on the upper edge of the upper slide.

For the solution of equations (1) and (2), a single slide only is required (Rule I.), and since the $p$ scale is already placed on the lower slide, the upper slide must be kept *fixed* during the solution. For equation (1), therefore, the scale of the dependent variable $V$ is placed on the lower edge of the upper slide, and the $N$ scale (direct) is placed on the upper edge of the lower and movable slide. The factor $n$ is taken as the independent variable, and its scale is placed on the lower part of the stock along with the $K$ scale. For equation (2), the factor $D$ is taken as the independent variable; but as there is not sufficient room on the stock to accommodate it as well as the $K$ and $n$ scales, it is placed instead on the lower (fixed) edge of the upper slide, along with the $V$ scale, and the index line $B$ is transferred to the upper edge of the lower slide. If there were room on the stock, then this index line (which should go on the lower edge of the slide) would be equivalent to a direct denominator scale. Since both it

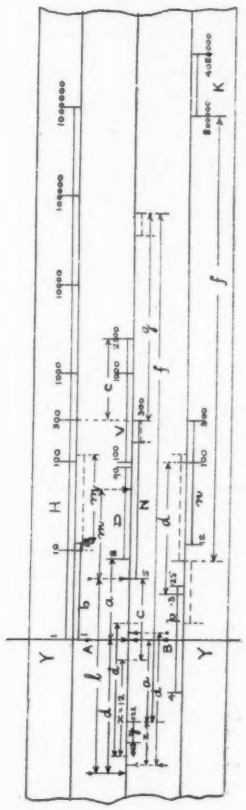


FIG. 27.

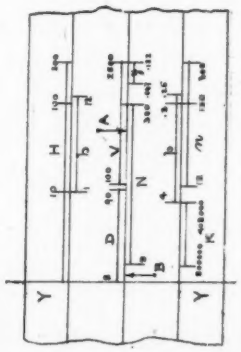


FIG. 28.

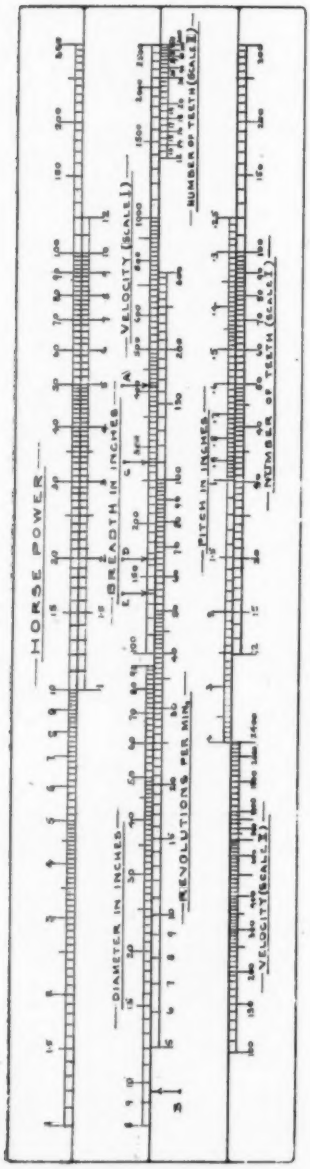



FIG. 29.—GEAR WHEEL CALCULATOR, BASED ON LEWIS FORMULA.

and its traversing scale are simply raised to the upper edges, for convenience, this index, when adjusted for an absolute constant correction, is still treated as a direct denominator scale.

The primary arrangement is first drawn with base scale unit = 1 in., without regard to the absolute constants, 12, 12, and 33,000. The final adjusted arrangement, to prevent confusion, is shown in Fig. 28. It is arrived at in the following manner:—The $D$ scale and index line $B$ are shifted distance $a$ to the left till $D = 8$ coincides with $YY$ (Rule IV.). The $V$ and $N$ scales are next shifted distance $c$ to the left till $V = 2{,}500$ comes in line with $H = 300$ (Rule IV.). Correction is next made for the denominator factor 12 in equation (1) by shifting the $N$ scale distance $x = 12$ to the left (Rule VI.). This $N$ factor is, however, a common numerator factor of equations (1) and (2), so that this negative shift also serves to correct the adjustment for the denominator factor 12 of equation (2). There still remains an adjustment to correct for the further numerator factor $\pi$ in the latter equation, and bearing in mind that index line $B$ is equivalent to a direct numerator scale, it is given a further negative shift $Z = 3{\cdot}1416$. Adjustment is now made for equation (3). The $p$ scale is shifted to the right distance $d$, till $p = {\cdot}3$ coincides with $n = 100$. Now since $p$ is a common factor of equations (1) and (3) its adjustment affects both sets of factors. Here two scales or equivalent index lines must be shifted to keep all the combinations in correct relative adjustment. For equation (3), index line $A$ is shifted distance $d$ to the left (Rule V.), and for equation (1), scale $N$ is shifted distance $d$ to the right (Rule V.). Factor $N$, however, is common to equations (1) and (2), and hence its adjustment must be compensated for by a corresponding adjustment of a factor scale or index line of equation (2).

The index line $B$ is therefore shifted distance $d$ to the right, and falls approximately on $D = 9{\cdot}5$. Adjustment is next made to bring the $K$ scale within the limits of the $H$ scale length. This scale is shifted distance $f$ to the left, till $K = 4{,}080{,}000$ coincides with $p = 4$, and the $y$ scale is shifted distance $f$ to the right (Rule V.). The 33,000 constant of equation (3) has still to be allowed for. This adjustment serves to illustrate the "partial shift" previously mentioned in connection with Rule VI. The $y$ scale is shifted distance $g$ to the left (Rule VI.) till $y = {\cdot}122$ comes in line with $H = 300$, and the index line $A$ (representing a denominator scale) is then shifted distance $l = (33{,}000 - g)$, Rule VI., to the

right. This brings the whole combination into complete adjustment within the limiting length of the $H$ scale. It is advisable, however, for convenient handling to transfer the $A$ index line further towards the right. As a final adjustment, therefore, the $b$ scale and index line $A$ are shifted distance $m$ till $b = 1$ coincides with $H = 10$ (Rule IV.). The approximate positions of the scales and index lines thus being fixed, the exact location of each has to be ascertained by calculation. For equation (1), when $p = \cdot 3$, $n = 100$, $N = 300$, the value of $V$ is 750, and the $N$ scale is therefore placed with $N = 300$ coincident with $V = 750$ (Fig. 29). For equation (2) with $N = 300$ and $V = 750$, the value of $D$ is 9·56, and index line $B$ is drawn coincident with this value. For equation (3), with $p = 4$, $K = 4{,}080{,}000$, $b = 1$, and $H = 10$, the value of $y$ is ·0202, and the index line $A$ is therefore drawn coincident with this value. (Figs. 28 and 29.)

The stress values, given in Table I., are suitable for cast-iron wheels. For other materials, they may be multiplied by the following coefficients :—

| Material. | Value of Coefficients. |
|---|---|
| Gunmetal, G.M. ... ... | 1·5 |
| Cast Steel, C.S. ... ... | 2·5 |
| Wrought Steel, W.S. ... | 3· |

The corresponding index lines $C$, $D$ and $E$ (Fig. 29) for each of these cases are located by shifting index $A$ distances of 1·5, 2·5 and 3 to the left of its position for cast iron wheels. (Rule VI.).

It will be seen that the design of this instrument affords an excellent exercise on the application in detail, of the rules, to nearly all the points of design previously discussed.

The complete instrument, with substituted $V$ and $n$ scales, is shown in Fig. 29. The "real" velocity and (number of teeth) scales are marked "Velocity Scale I," and "Number of teeth Scale I," while the substituted scales are marked "Velocity Scale II," and "Number of teeth Scale II." The upper scale of a 10-in. slide rule is taken as the base scale, and this gives an instrument about 13 in. long. The fineness of the division spaces on the $y$ or substituted $n$ scale is somewhat of a drawback. After the $n = 40$ value is passed there is a decided flattening of the curve, when the $y$ values are plotted on an $n$ base, as can be inferred from the table, and, in order to get finer sub-division of values than those tabulated, a much larger base scale would be necessary. This means an instrument of unwieldy proportions, if the scale limits adopted by the writer are adhered to. This question of size is, however, one which must be decided by each individual designer, according to the degree of accuracy he considers necessary. By restricting the limits of the fixed $H$, $n$ and $K$ scales, so as to reduce the circumference of the fixed scale circle as much as possible, a disk instrument, say from 12 in. to 13 in. diameter, may be constructed with a base scale about double the dimensions of the one chosen here. This would increase the dimensions of the $y$ scale considerably, and permit of its finer sub-division.

The direct rule of operation may be stated thus :—

(1) Place the slides in the "in" position. Keep the upper slide fixed; place the chosen revolutions against the velocity on Scale I and read the pitch against the number of teeth or *vice versa*, and the wheel diameter against index line $B$.

(2) Place the pitch against the velocity on Scale II and index line $A$, $C$, $D$ or $E$ against the number of teeth on Scale II, and read the horse power against the breadth of tooth.

Calculating charts to facilitate the application of Lewis formula to gear wheel design have, within the past few years, appeared in the technical journals; but the writer is not aware of any published description of a calculator for this purpose, and hopes that the one here submitted while serving as an exercise in calculator design, may also be found of service by the increasing number of designers who employ this expression for the design of machine cut gear wheels.

# Torsion-Meters, as applied to the Measurement of the horse power of Marine Steam Turbines.

*By J. HAMILTON GIBSON.*

The unsuitability of the ordinary steam engine indicator for the purpose of ascertaining the power developed by marine turbines had led to the adoption of the torsion-meter method of obtaining this information. Various types of this apparatus have been devised by which the torque of the revolving shaft can be read off, and the power transmitted through the shafting thus be calculated. The author, in the first part of his paper,* examined the method of obtaining the modulus of rigidity for a shaft, a value which must be known before a torsion-meter can be applied. In the following, a description of the various instruments themselves is continued.

## GARDNER'S ELECTRICAL TORSION-METER.

Some time ago, Mr. Gardner, of Fleetwood, made an electrical torsion-meter based upon the varying amount of current permitted to flow through a wire connected up to an ordinary ammeter (Fig. 7). Notched disks or interrupters are fitted to the shaft at a reasonable distance apart, and the notches are filled with non-conducting material so spaced that the conductor and non-conductor are the same length measured round the periphery of the disks. A brush lays lightly against the edge of each armature, the width of the brush tip being exactly equal to the length of a notch. When no torque is being transmitted, one brush is in full contact on one disk, and the other brush is adjusted so as to be just out of contact on the other disk. Therefore the circuit is interrupted, no current flows through the system, and the ammeter stands at zero. Immediately the shaft twists, however, the relative positions of the disks and brushes are altered, and current flows through the system until a maximum is reached when both brushes simultaneously overlap the conductors by half their width. The width of the brushes and notches are pre-determined to register the full power torque of the shaft.

Recently, Messrs. Barr & Stroud, the makers of the artillery range-finder which bears their name, have brought out a torsion-meter which is apparently based on the same idea as that of the "Gardner" apparatus: but no details are as yet available.

* The opening portion appeared in No. 3, pp. 164—168.

## INSTRUMENTS BASED ON THE ACTION OF A BEAM OF LIGHT.

Clever and ingenious as these mechanical and electrical instruments undoubtedly are, and manufactured with the greatest possible skill, they all leave something to be desired in the matter of accuracy, when it comes to the measurement of power. Every link in the chain between the main shaft and the recording apparatus introduces a possible source of error, and, as has been pointed out, an error even of the proverbial hair's breadth means a fairly large percentage error in the horse power result. In mechanical torsion-meters the multiplying gear necessarily involves a multiplication of whatever error there might be: whilst there are more insidious causes of error which creep in an electrical apparatus such as variations due to battery resistance, temperature effects, slight dragging of the commutator sections and brush tips, metallic dust or damp on the contact surfaces, and so on.

We turn therefore to other methods, and proceed to describe those torsion-meters which depend on the action of a beam of light.

## FRAHM'S INSTRUMENT.

Herr Frahm, of Germany, and Professor Hopkinson, of Cambridge University, have been working for some time on the same lines and each have evolved an apparatus so similar that probably the same description will suffice for both (Fig. 8). Starting with the concentric tubes and parallel disks of Fottinger's mechanical apparatus or their equivalent, the link work for recording purposes is dispensed with and a small

plane mirror is used pivoted to the edge of one disk, and oscillated by a projection on the other disk. As a relative movement between the disks increases, so the plane of the mirror is altered. A beam of light from a fixed light is projected on to the edge of the disks, and at each revolution of the shaft it is caught on the mirror and reflected on to a graduated scale. In a dark chamber such as a shaft tunnel the streak of light from the mirror on the rapidly revolving apparatus is almost continuous, and the graduations are read off with tolerable ease; but the almost inevitable spreading of the light beam adversely affects the accuracy of the reading.

### THE AMSLER APPARATUS.

Mention should be made of a neat torsion-meter device invented by Amsler of planimeter fame (Fig. 9). A concentric sleeve is fitted on a shaft and the free end brought close up to a fixed collar. A short scale is engraved on the collar, and a pointer or vernier on the free end of the sleeve, something like the marks on a micrometer calliper gauge. As the shaft twists the pointer moves along the scale. The problem now is to read the scale as it is flying round with the shaft. Here advantage is taken of the instantaneous duration of an electric spark. Contacts are fitted on the shaft just in advance of the scale, and a spark throws a powerful light on to the polished scale once in each revolution, so that the scale, however fast the shaft is revolving, appears to stand still, and thus the torque in degrees is read off directly.

### A FLASHLIGHT TORSION-METER.

The "Bevis-Gibson" flashlight torsion-meter (Fig. 10) has undergone searching tests during the last eighteen months. Starting with the well-known physical facts that the velocity of light is practically infinite, and that light rays travel in absolutely straight lines through air of even density, it was conceived that some simple means of applying these principles to a solution of the problem of shaft torque should be forthcoming. The usual trial and error work with which inventors are so painfully familiar followed, and eventually the flashlight torsion-meter was evolved and put into use. By a mental process of elimination it was decided at the outset that the less "gear" the better. The angles to be measured are so inconceivably minute, and in a rapidly revolving shaft the time intervals are so inconceivably short,

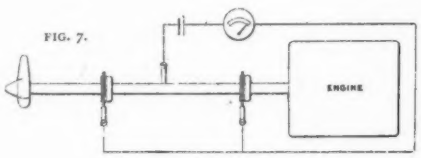
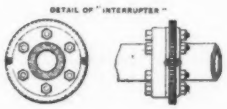



FIG. 7.



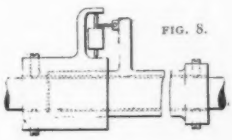
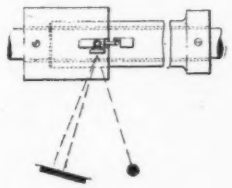



FIG. 8.



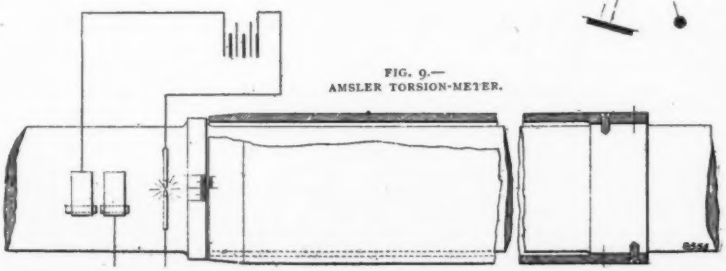


FIG. 9.—
AMSLER TORSION-METER.

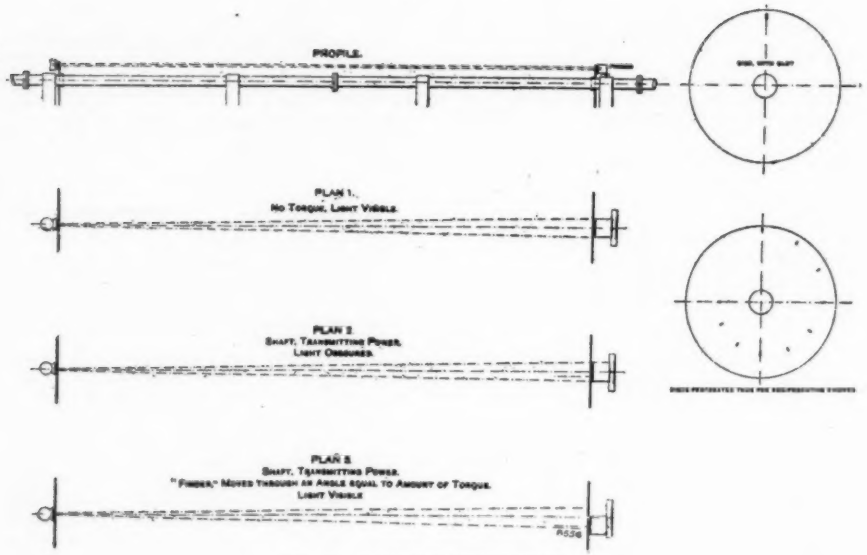



FIG. 10.—FLASHLIGHT TORSION-METER.

that nothing but an absolutely direct reading can give a true result.

The method adopted can be best shown by a diagram (Fig. 10). Two blank disks are mounted on the shaft at a convenient distance apart. Each disk is pierced near its periphery by a small radial slot, and these two slots are in the same radial plane when no power is being transmitted and there is no twist on the shaft. Behind one disk is fixed a bright electric lamp, masked, but having a slot cut in the mask directly opposite the slot in the disk. At every revolution of the shaft, therefore, a flash of light is projected along the shaft towards the other disk. Behind the other disk is fitted the torque-finder, an instrument fitted with an eyepiece and capable of slight circumferential adjustment. The end of the eyepiece next its disk is masked except for a slot similar and opposite to the slot in the disk. When the four slots are set in line, a flash of light is seen at the eyepiece every revolution, and if the shaft revolves quickly enough the light will appear to be continuous. This effect is apparent at anything over 100 revs. per min. At lower speeds the flash is seen to be intermittent, but this in nowise effects the accuracy and reliability of the result. At each end of the shaft, therefore, we have what is virtually an instantaneous shutter fixed, be it noted, directly to the shaft, and there is no connecting link or gear between the disks either mechanical or electrical, except the beam of light which flashes once in each revolution clear through the two shutters. Let us suppose now the shaft to be transmitting power. One disk lags behind the other by a definite amount, and although three of the slots are still in line, the fourth slot, namely, that in the lagging disk, effectually blanks the flash and no light is seen at the eyepiece.

This is where the function of the "torque-finder" comes in. To pick up the light again the eyepiece must be moved by an amount equal to the circumferential displacement of the lagging disk. This is accomplished by manipulating the micrometer spindle of the torque-finder, on which is a scale and vernier graduated in degrees. While the scale is fixed its vernier moves with the eyepiece, and the graduations are so marked that by the aid of a simple microscope conveniently hinged, differences of $\frac{1}{100}$ of a degree can be readily discerned. For shafts of ordinary size the scale is set 13·6 in. radius from the centre of the shaft, so that the degrees are about $\frac{1}{4}$ in. apart. One-hundredth of a degree, therefore, means $\frac{1}{100}$ of $\frac{1}{4}$ in., or $\frac{1}{400}$ of one inch. As an ordinary shaft twists 1 deg. in 10 ft. at full power, it is therefore possible to get the

shaft horse power to within 1 per cent. of full power. But as it is frequently possible to fit the disks 40 or 50 feet apart, even this accuracy may be improved upon, and powers ascertained to within $\frac{1}{4}$ of 1 per cent. of full power. Users of the ordinary steam engine indicator will readily appreciate what this means, for indicated horse powers are frequently wofully erratic. When we consider that a steam engine cylinder is often some thousands of times greater in area than the small indicator piston, we get some faint notion of the effect of multiplication of error. Add to this the friction of the engine piston, the piston rod, the guides, and the connecting rod joints, and we begin to realise how much more reliable is shaft horse power than indicated horse power. For purposes of scientific data, especially in reference to ship propulsion, the latter term will no doubt soon become obsolete, and retire into the comparative obscurity of nominal horse power and other like terms.

The slots in the torsion-meter disks are necessarily of appreciable width, and in moving the torque-finder over the light is visible for some distance along the scale. The light comes into view, attains a maximum amplitude and brightness and fades away as the eyepiece moves along the scale. If it were possible to gauge the exact point where the light attains a maximum, that is the point that would be used. Failing this, however, use is made of one edge of the slot. The finder is moved always in the same direction in taking readings, and stopped at the exact point where the light is cut off. So delicate is the sense of sight that a movement of $\frac{1}{100}$ of a degree is sufficient to mark the difference between light and darkness. A zero reading is taken when the shaft is revolving idly, if possible at or near full speed, and this reading forms a base and is subtracted from any subsequent power readings.

Let us see how this works in practice by employing a mechanical lantern slide. First, suppose the shaft to be revolving idly. The finder is moved over until the light is just disappearing, and the vernier is seen to be standing at ·53 deg. Now, suppose the shaft to be transmitting power. The disks have twisted relatively to one another, and no light is seen until the torque-finder is moved the same amount. Having picked up the light, the finder is worked gently over until the light is just disappearing again. The reading is now 2·39 deg. Subtract from this the zero reading of ·53 deg. and we get the true torque, namely, 1·86 deg. Now, to apply our shaft horse power diagram (Fig. 11) referred to in the earlier portion of this paper. We will suppose that the revolutions are 475 per min. The torque is 1·86 deg., and finding the intersection of the lines on the diagram the power is seen to be 3,620.

It is perhaps scarcely necessary to point out that the whole operation takes much less time than its description. Indeed, it is possible to produce the shaft horse power on a trial trip immediately on the termination of each measured mile run, and to hand a slip to the officer in charge similar to that shown below, containing all the information, in plenty of time for him to make any necessary adjustments before coming back on the straight for the next mile.

### MODIFICATION FOR RECIPROCATING ENGINES.

For reciprocating engines a simple modification of the flashlight torsion-meter enables the operator to take several read ings—usually twelve—in one revolution of the shaft. The disks are perforated with 12 slots arranged in the form of a spiral—one at each 30 degs. of the circumference (Fig. 10). The lamp and torque-finder must be moved radially from the shaft, so as to bring them into line with each corresponding pair of slots in the disks. By spotting the readings on a sheet of squared paper and sketching in the curve (Fig. 12), we get an actual twisting moment diagram from which

FLASHLIGHT TORSION-METER RESULTS.

Vessel, H.M.S. *Indispensable*. Trial, Official Full Power.

| Shaft. | | Run. | Steam at H.P. Recvr. | Revs. per Minute. | Reading. | Degrees Torque. | Shaft Horse Power. |
|---|---|---|---|---|---|---|---|
| Stard. | Wing ... | IV | 180 lbs. □″ | 710 | 5·90 | 1·26 | 8,300 |
| | Centre ... | | | 680 | 6·02 | 1·20 | 7,480 |
| Port | Centre ... | | | 687 | 4·64 | 1·21 | 7,520 |
| | Wing ... | | | 707 | 5·74 | 1·23 | 8,270 |
| Mean revolutions ... ... ... | | | | 696 | TOTAL ... .. ... | | 31,570 |

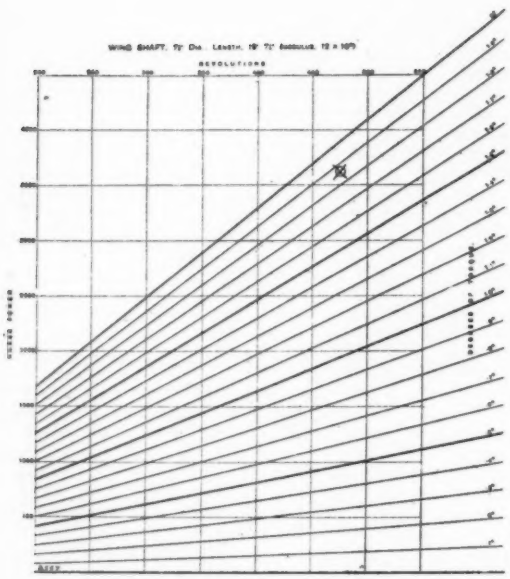


FIG. 11.

the mean torque is readily obtained. The mean torque with the revolutions is then referred to the power diagram and the shaft horse power read off as before.

This modification of the apparatus is only required in the case of shafting driven by reciprocating engines. In a recent vessel an interesting comparison in this connection was made (Fig. 13). A crank-effort diagram was built up in the usual way from the indicator diagrams, due allowance being made for the effect of the inertia of the moving parts, and the torsion-meter twisting moment diagram drawn down to the same scale. The latter curve corresponds closely with the crank-effort diagram, but the variation from the mean is greater in the shaft torque diagram, due probably to the action of the propeller and the torsional oscillations thus set up. It will be noticed that the dotted shaft diagram is consistently below the crank-effort diagram, the mean difference being about 10 per cent. This difference corresponds almost exactly with the result obtained by steaming and indicating the engines disconnected from the propeller in the west basin before the underway trials, and forms a striking check and corroboration of the two curves.

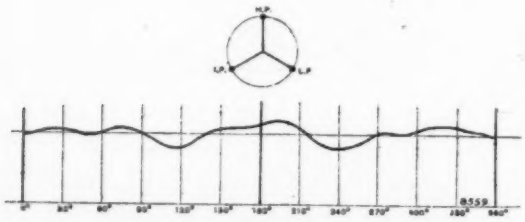


FIG. 12.—MEAN TWISTING MOMENT DIAGRAM FOR RECIPROCATING ENGINE.

## SPECIAL APPARATUS FOR A LIMITED LENGTH OF SHAFTING.

Cases sometimes occur, especially in modern warships, where a long length of shafting is not available for torsion-meter purposes, and recourse must be had to a special form of apparatus.

To meet this contingency, another modification of the flash-light torsion-meter is used, in which the beam of light, instead of flashing axially along the shaft, is made to flash radially through slots in concentric drums, and is caught by a torque-finder at some distance from the shaft axis (Fig. 14). The drums are fixed to the shaft only two or three feet apart, and the relative movement due to shaft torque is naturally very much less than that of the disks in the axial form of torsion-meter. A masked lamp is fitted inside the smaller drum next the shaft, and so close to the drum that when the shutter opens the source of light is exactly at the shutter. The outer drum is made as large in diameter as can be conveniently arranged, the radial distance between the drums as compared with the distance of the torque-finder from the source of light giving by direct proportion the required multiplication of effect, and enabling the torque as before to be read off with extreme accuracy, considering the short length of shaft available. The light in this case is cut off by three knife edges—one at the lamp, one at the inner drum, and one at the outer drum, the eyepiece being fitted with a diaphragm pierced by a minute pin-hole in the

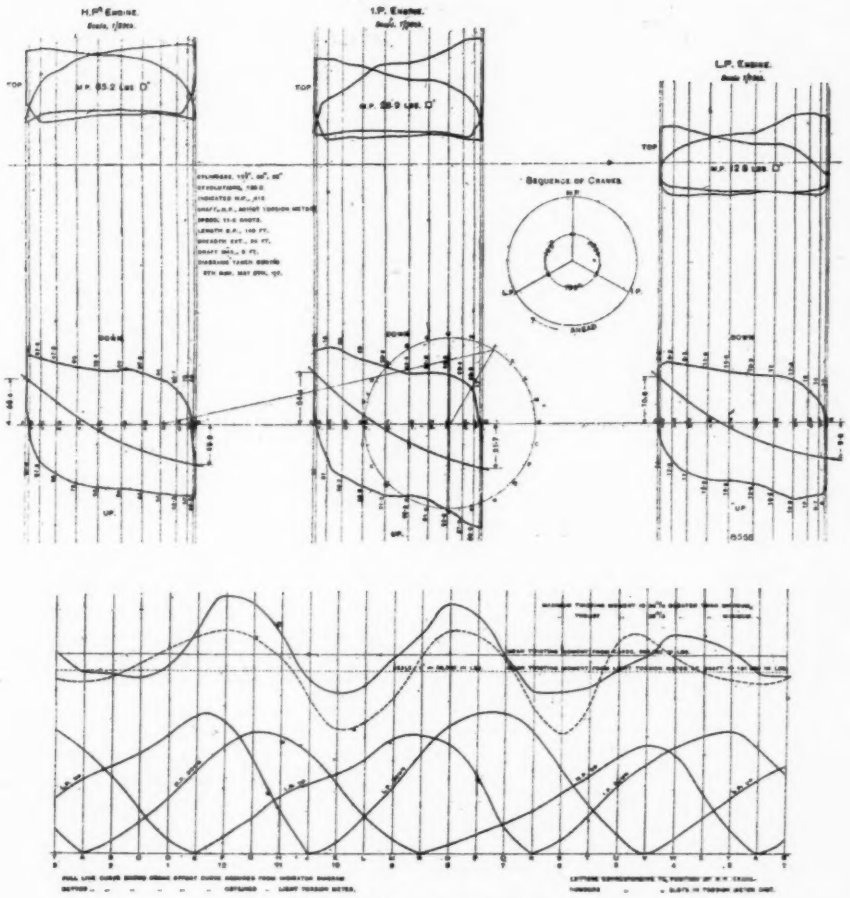


FIG. 13.—COMPARISON OF CRANK EFFORT AND TORSION-METER DIAGRAM.

centre. The extreme sensitiveness of the apparatus is almost incredible. The angle of the flashing beam proceeding radially from the shaft can be measured to $\frac{1}{1000}$ of a degree, so that although only three feet of shafting may be available the result is as good as if a 30 feet length had been used with an axial-ray apparatus.

Radial flash torsion-meters are not quite so simple in construction as the axial-flash type: but there are certain obvious advantages besides its applicability to a short length of shafting. For instance, the flash might be led vertically upwards through a tube in a deck immediately overhead and the readings taken at will in the seclusion that a cabin grants, instead of in the engine room or tunnel. In the practical application of the flashlight torsion-meter to various vessels fitted with steam turbine installations some very interesting results have been forthcoming, which are set out in tabular form.

Attention is specially directed to the immense range of the apparatus. Some of the low powers recorded are less than half of 1 per cent. of the full power. If indicated horse powers of such small amount

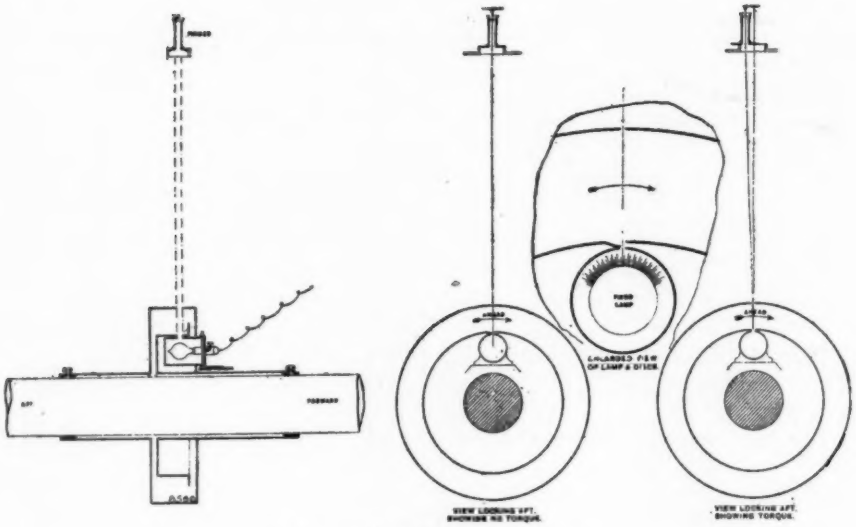


FIG. 14.—RADIAL FLASHLIGHT TORSION-METER.

were required to be taken from a piston engine, the indicator spring would have to be changed for a very weak one to get a reasonably accurate card: but no such change is required in the apparatus we are considering.

Then again the distribution of power in a turbine installation can only be approximately estimated. The steam is turned into the high pressure turbine and left to follow its own devious course through the successive turbines on its way to the condenser. At low powers it is sometimes found that the high-pressure turbine shows the most power, whilst for overloads the lower pressure turbines have the advantage.

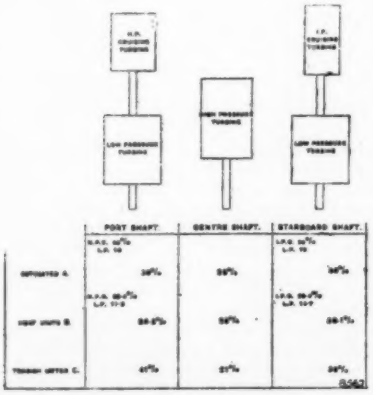
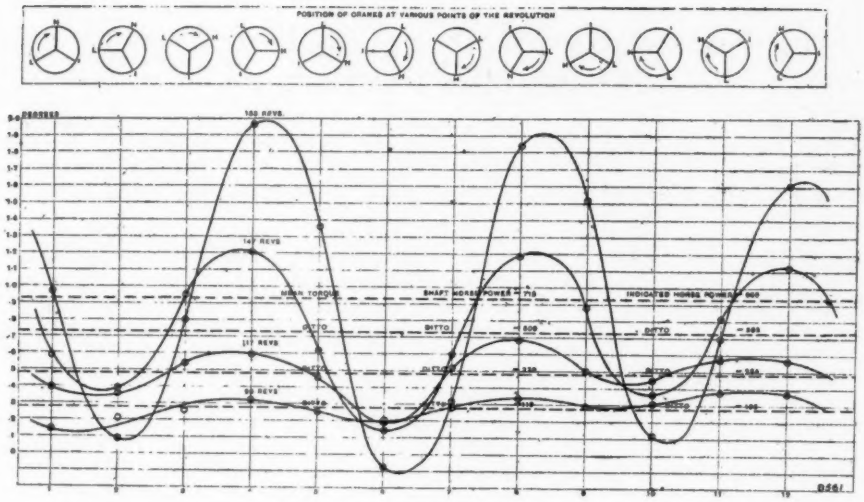


FIG. 15 —HALF-POWER SPEED RESULTS.

### FLASHLIGHT TORSION-METER.

Actual Readings and Corresponding Horse Powers taken during Trial Trips under varying conditions of Displacement and Propellers.

| Turbine Shaft. | Degrees Torque. | Revolutions per Minute. | Shaft Horse Power. | Shaft Horse Power Total. |
|---|---|---|---|---|
| Starboard l.-p. ... | 1·43 | 482·9 | 2,775 | |
| Centre h.-p. ... | 1·69 | 461·2 | 2,600 | 7,975 |
| Port l.-p. ... | 1·37 | 472·8 | 2,600 | |
| Starboard l.-p. ... | 1·32 | 461·2 | 2,410 | |
| Centre h.-p. ... | 1·65 | 426·8 | 2,330 | 6,940 |
| Port l.-p. ... | 1·24 | 457·3 | 2,200 | |
| Starboard l.-p. ... | 1·15 | 426·4 | 1,970 | |
| Centre h.-p. ... | 1·52 | 417·6 | 2,080 | 5,960 |
| Port l.-p. ... | 1·13 | 418·9 | 1,910 | |
| Starboard l.-p. ... | 1·05 | 418·4 | 1,765 | |
| Centre h.-p. ... | 1·52 | 422·3 | 2,120 | 5,555 |
| Port l.-p. ... | 1·02 | 415·5 | 1,670 | |
| Starboard l.-p. ... | ·21 | 198·6 | 162 | |
| Centre h.-p. ... | ·27 | 206·3 | 185 | 495 |
| Port l.-p. ... | ·19 | 183·5 | 148 | |
| Starboard l.-p. ... | ·22 | 146·7 | 88 | |
| Centre h.-p. ... | ·21 | 171·4 | 87 | 257 |
| Port l.-p. ... | ·13 | 144·8 | 82 | |
| Starboard l.-p. ... | ·07 | 46·3 | 13 | |
| Centre h.-p. ... | ·05 | 86·1 | 15 | 37·2 |
| Port l.-p. ... | ·01 | 24·4 | 9·2 | |


POSITION OF CRANKS AT VARIOUS POINTS OF THE REVOLUTION
DEGREES
180 REVS.
147 REVS
117 REVS
90 REVS
DITTO
DITTO
DITTO

# The Superintendent of Motive Power on American Railways.

THE superintendent of motive power, the superintendent of rolling stock, or the mechanical superintendent, as he is variously called, of the American railroad, is as good an example in evolution both in man and position as can well be found. In 1867 and 1868, at the time of the organising of the Master Car Builders' and Master Mechanics' Associations, there was not a man in the country bearing any one of the three titles with which this article opens. Not only was there not a single man bearing the title but there were none with the duties and responsibilities now pertaining to those positions. In fact it was not until April 1, 1872, that the title was created and used on the Pennsylvania Railroad.

### HIS PROTOTYPE, "THE MASTER MECHANIC."

The name of the two great railroad mechanical associations fully expresses the position and status of the men in charge of the car and locomotive departments at the times of their organisation. They were "master car builders" and "master mechanics" in the strictest sense of the words. They were masters of their trades, they were men who had entered the shops as boys, and frequently as very young boys, and who by ability, energy and perseverance had worked their way up, in spite of all obstacles, through the several positions of apprentice, journeyman, shop foreman, and master. A great majority of the master mechanics had been locomotive engineers, and not a few had come up through the successive steps of wiper, fireman, engineer, roundhouse foreman, and master mechanic. Their educational advantages had almost invariably been meagre, and what they knew, they knew not by study, but by the hard knocks of practical experience in a rough life upon the road or in the shop.

Many of them were readers, and an examination of their libraries would show a collection of the few books that were available upon locomotive work at the time. In this respect the master mechanics were better off than the master car builders, as there was some literature on the locomotive but absolutely none in regard to car construction. Indeed this paucity of literature on car construction and maintenance has been one of the wonders of the day, for it was not until very recently that there has been anything on the subject barring the Car Builders' Dictionary, first published in 1887. This may have had some influence, but probably it was due to the fact that the locomotive is a more intricate and higher type of a machine than the car, that the master mechanic was considered the superior of the master car builder, though the two departments were entirely separate and distinct, and it was not until late years that the former had any jurisdiction over the latter.

Growing up in this way, and with none of the incidental advantages coming from a higher education, these men were frequently lacking in the refinement of manners that goes with the training, and were, therefore, regarded as skilled mechanics, and were treated as such. They were supposed to know, and did know, all there was to be learned of the practical operation of a locomotive, but they did not have the scientific training to work out new designs, or the courage to execute ideas that seemed to their own good sense worthy of adoption. If a certain part of a locomotive gave trouble by breaking, they remedied the trouble by making it heavier, but did little to study

the stresses to which the part was subjected and dispose the metal so as to best meet the same. The indicator was an unknown factor in locomotive operation, and an indicator card might as well have been a cuneiform inscription as far as any information it would have given to the majority of these men.

It must not be inferred from this that the master mechanic of the early seventies was a stupid person or an ignoramus. That is very far from the case. He was alert with the keenest of intelligence and equipped with a world of information, that never has been and never will be learned from books. He had the confidence of his superiors up to a certain point, but unfortunately that point fell far short of his deserts.

Few of these men really undertook the designing of new locomotives. In fact it is almost incredible how few roads had a draughtsman among its employés of the mechanical department. It is less than twenty-five years ago that one of the greatest trunk lines of the country employed its first draughtsman in the locomotive department at a salary of $50.00 a month. If a new locomotive was to be built in the shop, it was usually a copy of one already in existence, or if changes were to be made, the master mechanic indicated what they were to be, and probably made the few drawings that were to be used with his own hands, and the rest was done by the rule of thumb in the shop.

Under these conditions salaries were low. It was not an uncommon thing to find a master mechanic working for lower pay than some of his own engineers in fast passenger service. Salaries of $100.00 a month were considered good, and the man who received $2,500 a year was a nabob.

Such a state of affairs is incomprehensible if viewed from the standpoint of the necessities of the railroad for trained men; but is readily understood if the sources of supply are considered. At that time there was but one technical school in the country that gave an approach to real training in mechanical engineering, and even that was far below its own present high grade of efficiency. It was absolutely necessary that the man in charge of the locomotives of a railroad should be thoroughly familiar with them in all of their practical details, and the only way in which this familiarity could be obtained was by work in the shop and on the road. At the time the country was held in the grip of the scholastic system of education. Men who could afford to give their sons an education, sent them to college to train their minds on Latin and Greek, and the whole social instinct of the class shunned every thought of contact with the grease and dirt of the shop. The natural result was that these positions were left to the hard-working boy who had to earn a living first and get an education afterwards.

### HIS DEVELOPMENT—THE INFLUENCE OF TECHNICAL SCHOOLS.

The struggle of the technical schools for recognition as institutions of learning was gradually successful, and their trained graduates in looking about for positions naturally turned to the railroads as a promising field. Their entrance was by no means easy. The whole railroad community, from the president to the water boy of the train, was steeped in the ideas that "these theoretical fellers" were "no good," and what was wanted was "practical experience." The latter part of the idea, so far as practical experience is concerned, is all right, and it remained for the graduate of the technical school to show that when he had added "practical experience" to his theoretical training he was far and away a better man than the one with the practical experience alone ever was or could ever hope to be.

We find, then, in the early eighties that when an old-time master mechanic died or retired, that he was being succeeded by one of the new school, a man who had had a technical training, and who after graduation had donned overalls and served time in the shop or on

the footplate of a locomotive: a man who brought a trained mind to bear upon the problems of his work and with whom much of the delay incident to trial and error in gaining experience under the old *régime* was eliminated. In short, he was capable of taking short cuts to results and did not depend upon a long series of mistakes to indicate the proper course.

### HIS ADVENT.

With the advent of this man into the field we find a gradual change in the character of the proceedings of the associations. The title of superintendent of motive power had appeared here and there; then it became common, and at last it, or its equivalent, is held by the head of the motive power department of all large roads and some small ones, while that of master mechanic is given to those who have risen to a position in charge of shops or divisions. Gradually, too, the head of the locomotive department has taken charge of the cars, and his title is sometimes varied to "superintendent of rolling stock," or "mechanical superintendent," to meet this condition, although very frequently the "superintendent of motive power" is in full charge of the car department. It is a mere matter of name and does not change the ordinary duties of the office. Under this changed condition of affairs the master car builder has become really an assistant superintendent of motive power in charge of the car department. His authority is the same as it ever was, but he, too, has changed from the self-made man who has worked his way up from the ranks to one technically educated.

The duties of these men have grown with the office. We no longer find the superintendent of motive power in the roundhouse, keying up an engine with his own hands as the master mechanic frequently did in the old days. His duties are largely executive. Still behind it all must be a wide and intimate knowledge of the details of the practical working of the mechanisms under his care. The demands that are made upon him in ability, knowledge and experience are such that the master mechanic of the old school cannot hope to meet, and he will soon, except in cases of exceptional ability, cease to exist as the recognised head of the mechanical department of American railroads.

It would naturally be inferred that the abler man with increased responsibilities and duties would have a greater influence in railroad affairs than his predecessor. It is true that he has, but his real position is not at all in accord with his deserts, his responsibility or his ability. It is safe to say that there is no more able body of engineers on earth than the superintendents of motive power of the United States, who constitute the membership of the Master Car Builders' and Master Mechanics' Associations.

### PRESENT POSITION: NOMINAL, NOT REAL HEAD OF THE MECHANICAL DEPARTMENT.

And it is safe to say that the great majority of railroad managers will not demur to that assertion. But, as a matter of fact, their authority is limited: so limited, in some places, that they are little more than clerks in charge of their departments. They are capable of designing and operating every type of machine that falls within their jurisdiction, and their judgment is as good as the best; but in the matter of final decisions as to the policy to be pursued or the type of engine to be used for certain services, these are too frequently made of the general manager or even the chairman of the board. It takes years to eradicate an old idea, and the old ideas, that is the bane of present motive power service, is to the effect that the master mechanic is merely a skilled labourer, that he has practical experience, but if a new locomotive is to be designed or built, it had best be left to the contracting builder, who for years stood behind that official and did that class of work for him.

### SOME EXAMPLES ILLUSTRATING HIS LIMITED AUTHORITY.

The superintendent of motive power is all very well, but to invest him with the absolute power and pay him the

salaries of his European brother is an unheard of condition. That he will grow up to this position in time there is no doubt, but at present he is in a transition state between the old and the new. Sometimes he is not even consulted as to the type of power to be used, and a few examples will serve to illustrate the humiliating conditions in which these men frequently find themselves.

A certain road had a number of consolidation engines that were giving satisfactory service but which the superintendent of motive power thought could be improved. The general manager knew of the first but not of the second proposition. Without the knowledge of the motive power official, or without so much as informing him that the road was in the market for locomotives, an order was placed for a number in duplication of those on hand, and the first intimation received was a request to send an inspector to look them over.

A representative of a locomotive building firm was in conference with the general manager of a road, regarding a lot of engines, for which he was in the market. They were talking over the general conditions, of the track, grades, service, speeds, train weights and the like, when the representative suggested that before a final decision were reached, it would be well for him to consult with the superintendent of motive power. "Oh, there is no need to go and see him," said the manager, "we don't pay any attention to what he says."

On another occasion an effort was being made to persuade a superintendent of motive power to try one or more compound locomotives among a lot of engines that were to be ordered. He flatly refused to entertain the idea, and added that he would not consent, under any circumstances, to have a compound locomotive on the road. Within ten days the general manager placed an order for twenty-five compound locomotives without his knowledge.

### UNCERTAINTY OF HIS POSITION.

Added to this unsatisfactory condition of affairs is an uncertainty as to the tenure of office that is appalling to the man who is dependent upon his salary. The railroads are essentially governed from Wall Street. A change in the holding of stocks means a change of management, and when the new president comes in he brings his own train of supporters, and departmental heads drop off all along the line. Previous records of faithfulness and ability apparently count for nothing. An intimate knowledge of the road and the requirements of its service are regarded as of no value compared with personal acquaintanceship. The result is that the new man, however able he may be, fails, from the lack of this personal knowledge of local conditions, to make as good a showing as his predecessor, and his head is apt to drop too, unless he has a strong personal influence that will hold him in place until he can learn what is needed and adapt himself to these new conditions.

It must not be thought that this is a universal state of affairs, as it is not, for, in some places, tenure of office is practically for life, but in the majority of cases it exists to such an extent as to make a most unpleasant condition of affairs.

### FUTURE PROSPECTS.

There are indications, however, that we are growing out of it, and that the time will come when the nominal will be the real head of the mechanical department in all cases, and receive the reward that the merits of the individual deserve. In the meantime the roads are being faithfully served by as competent a set of men as can be found, and it is to them, and the vast amount of original work done by them individually and in their associations that the material progress in American railroading is due.

# Steam Turbine Engineering.

*By S. L. PEARCE, A.M.Inst.C.E., M.I.Mech.E., M.I.E.E.*

Perhaps the most important engineering feature of the past decade has been the application of the steam turbine to electrical generation and marine propulsion. It is chiefly to its association with the former that the turbine owes its rapid development, although its applicability for the latter purpose is hardly less important. In the following paper* the author reviews, in a brief and concise form, some of the elementary principles which form the basis of turbine design, and considers the development of the many types of the modern steam turbine. A short description of the leading practical examples of these various types is given, together with some data of their performances. Some comparisons are also drawn between turbine and reciprocating units.

## Elementary Theoretical Considerations.

The question is frequently asked: What is a steam turbine, or what are the forces which cause the rotation of the movable portion of the turbine? The answer to the latter part of the question is that rotation is caused as the result of differences of pressure at different points on the internal surfaces, due to the momentum of the steam passing through.

Jude defines a turbine "as a prime mover in which the gradual changes in the momentum of a fluid are utilised to produce rotation of the mobile members." Starting with this definition and taking the kinetic energy of steam as given by the expression $\frac{1}{2}MV^2$ and its momentum by $MV$ (adopting the usual units for mass, time, and velocity), in order therefore to impart the energy of the steam to the revolving portion of the turbine, a change in its *velocity* must take place.

Here we have at once the broad theoretical distinction between a turbine and a reciprocating unit—the former depending not on pressure action but velocity change—the latter operating with statical pressure on pistons.

The grouping of turbines under two classes is commonly general, viz.:—(*a*) Impulse turbines. (*b*) Reaction turbines.

In the reaction turbine there is a transformation of the potential energy of the steam into kinetic energy within the revolving as well as the fixed portion of the turbine; in other words, the steam expands both in the fixed and running vanes. In the impulse turbine this is not the case, the transformation of the potential energy of the steam taking place in the fixed external portions or passages prior to the steam entering the revolving portions. In other words, the expansion of the steam is confined to the fixed portion, which may be the inlet nozzles or guide vanes. Following on these broad definitions it is obvious that in the case of the reaction class there is a difference of velocity and pressure between the inlet and outlet side of the revolving member—and the inlet side of the revolving vane has to work in a medium of higher pressure than the outlet side—consequently the conditions are present for a loss from leakage, unless the clearances between the fixed and revolving members are kept very fine.

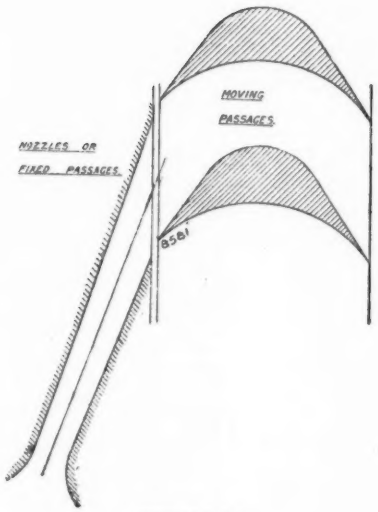
In the case of the impulse turbine, there is no difference of pressure and velocity between the inlet and outlet sides of the revolving member, or rotor, as it may be termed, consequently there is no possibility for steam leakage to take place—an advantage which may be set over against the probably higher frictional losses of the impulse type.

Although the terms "impulse" and "reaction" are convenient to use, the point must be emphasized that the characteristics of the many types of turbines cannot be grouped completely under one or other of these headings.

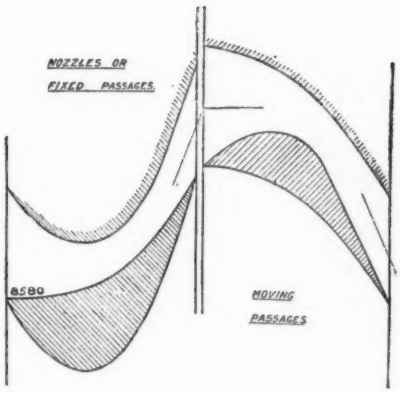
Speaking generally, it may be said that in the "Impulse" type the steam is expanded in the "guides" or "nozzles" only, where the whole of the potential energy of the steam is transformed into kinetic energy, through successive and graduated stages, from full inlet pressure to atmospheric pressure or vacuum.

In the "Reaction" type, the steam enters the turbine at the boiler pressure and temperature, and is gradually expanded through a long series of wheels and guide vanes.

* Proceedings of the Manchester Association of Engineers (abridged).




IMPULSE TYPE.




REACTION TYPE.

The velocity of flow corresponding to the change of potential into kinetic energy when steam is expanded from 160 lbs. pressure to 3 lbs. absolute is 3,660 ft. per second.

The ratio of peripheral blade or vane velocity to the theoretical steam velocity to obtain the best results is in the case of the "Reaction" turbine 2:3, and for the "Impulse" turbine 1:2.

A third class may be added which consists of the combined "Impulse and Reaction" types.

Class 1 may be further divided into simple and compound impulse turbines. The latter class, viz., Compound Impulse Turbines, may be further sub-divided into three groups:—

(*a*) Those in which the turbine is compounded for pressure. (*b*) Those in which the turbine is compounded for velocity. (*c*) Those which are a combination of (*a*) and (*b*).

### The Simple Impulse.

The principal feature of this type is the expanding nozzle in which the steam is expanded down to nearly atmospheric or condenser pressure. The steam issues with a velocity corresponding to the drop in pressure and impinges on the single wheel, thereby giving up as much as possible of its kinetic energy. On passing through the wheel vanes the velocity of the steam falls to the absolute limit—the pressure of the steam at the outlet and inlet passage being practically constant. It is obvious that for this type of turbine to have any degree of efficiency the wheel diameter and the peripheral velocity must be high, and unless very large diameter wheels be used gearing must be resorted to to bring the turbine into line for commercial usages.

The simple impulse turbine is always associated with the name of De Laval, from whose inventive work many of the features of the modern steam turbine have been developed. As a small unit it has earned a commercial success, but whilst many of the other types of turbines are being built up to 10,000 h.p. and even 20,000 h.p., the De Laval unit appears limited to 300 h.p.

In the larger sizes steam is admitted to a series of nozzles arranged at intervals around the periphery of the wheel and usually controlled by several shut-off valves, which are varied according to the load. Their number and shape are decided with reference to the steam admission pressure, degree of superheat to be used, and vacuum.

Messrs. Greenwood & Batley provide their "De Laval" turbines with such a number of nozzle holes as to render it possible to put in any required number of nozzles for a variable steam admission pressure of from 75 lbs. to 225 lbs.

The wheels are made of a high grade carbon steel with solid hubs, the section of the wheel gradually decreasing to the rim. The hub is not bored out, which would have the effect of seriously decreasing the strength of wheel, but is recessed at each end into which the flanged ends of the flexible shaft fit and are bolted solidly in place.

Grooves are milled in the rim in a crosswise direction into which are fitted the "vanes" or "buckets" of drop forged steel.

Next in importance to the nozzle is the flexible shaft. Such high speeds as 30,000 for the 5 h.p. size down to 10,000 for the 300 h.p. size entail enormous centrifugal forces, and it is quite impossible to deal with these by means of rigid shafts. Hence De Laval employed a flexible shaft of considerable length which permits the wheel to rotate about the centre of its mass instead of its geometrical centre. The shaft for a 300 h.p. turbine is only $1 \cdot \frac{5}{16}$ in. in diameter.

As we have seen that the steam is expanded down to atmospheric or condenser pressure in the nozzles, the wheels therefore rotate in a medium of low density with equal pressure on each side. There is therefore no need to make provision for end thrust.

As it is usual in the "De Laval" type to use small diameter wheels with gearing to reduce the peripheral speeds, considerable attention has been given to this portion of the turbine. The teeth of the pinions are cut directly on an extension of the flexible shaft. Double helical gearing is employed to bring about the speed reduction.

Up to 30 h.p. solid steel gears are used, but for the larger outputs cast-iron centres with mild steel rims are employed. The success in running these gears at such a high speed is due partly to the fine pitch, and the spiral angle of the teeth which brings a large number of teeth into mesh at one time, making the working pressure per tooth very small.

The principal losses in the "De Laval" turbine occur at the nozzles. In addition there are losses due to friction of the steam passing over the vanes, and of the wheel revolving in the steam, otherwise disc friction, and losses due to unspent kinetic energy in the steam passing to the atmosphere or condenser.

Representing the input of energy supplied in the steam admission to the nozzles by 100, the nozzle losses account for 12 to 14, disc friction 4 to 5, and friction of steam passing over the vanes 9 to 10, and the residual kinetic energy by 8 to 10. Steam admission pressure, vacuum and superheat all have a material bearing on steam consumption figures. Dealing with full loads only there is, however, no advantage to be gained from using higher initial pressures than 160 lbs. approx. Up to this figure, however, the decrease in steam consumption may be put down at some 2 to $2\frac{1}{2}$ per cent. for every 10 per cent. increase in steam admission pressure.

Again for vacuum the average decrease in steam consumption for each percentage increase in vacuum is 0·5 per cent.

As regards superheat, there appears to be no advantage in using anything higher than 212° F. A superheat of 50° F. will bring about a decrease in steam consumption of 4 per cent. Some 4 per cent. decrease in steam consumption can be shown by raising the superheat from 50° F. to 120° F., and a further 2 per cent. decrease by raising the superheat of 120° F. to 212° F.

The steam consumption of the "De Laval" turbine for any rated output from 10 to 200 k.w. with absolute pressure of 160 lbs. and $27\frac{1}{2}$ in. vacuum and no superheat may be taken to vary between the following limits

Full load 10 k.w. 37 lbs. per k.w.h.
to Full load 200 k.w. 23 lbs. per k.w.h.

The second example of the single impulse turbine which should be briefly touched upon is the now defunct and discarded "Riedler-Stumpf," which was brought out by the Allegemeine Elecktricitats Gesellschaft of Berlin.

Instead of using small diameter wheels rotating at very high speeds, the "Riedler-Stumpf" wheels were of considerable diameter, and the permissible peripheral speed being the same as in the "De Laval," consequently a lower number of revolutions were obtained on the driving shaft. The difficulty was to obtain wheels of large diameter of accurate strength and balance and homogeneous structure.

With a "De Laval" type running at a speed of 10,000 r.p.m. the wheel diameters are approximately 30 in., and the peripheral speed in feet per sec. 1,400 approximately.

To keep the same peripheral speed but to reduce the revolutions per minute made by the turbine to some 3,000 r.p.m. would require a wheel diameter of some 8·5 ft. Some such proportions as these were employed in the "Riedler-Stumpf." It was hoped that by reducing the shaft speed to some 3,000 r.p.m. the direct drive of electrical machinery without the aid of intermediate gearing would be possible.

The same general principles in its design were embodied as those used in the "De Laval," although details of construction differ somewhat. The nozzles discharge the steam jets radially, *i.e.*, in the plane of the wheel, instead of from the side as in the "De Laval" type. A double row of parallel "vanes" or "buckets" were used in the larger sizes, such as the 2,000 h.p. set installed at Moabit Central Electric Station, Berlin.

The impossibility of obtaining low speeds

by the use of a single wheel led to certain suggested modifications in the design—the first of which was the introduction of a reversing nozzle—so that a reduction in the steam velocity could be brought about by using two successive impingements of the steam upon the single wheel. This is akin to Pilbrow's original invention on these lines.

The next development was to introduce two or even four pressure stages, with the single wheel of each stage acted upon twice by the steam. The design did not prove economical, and the A. E. G. Co, having acquired the "Curtis" patents, the "Riedler-Stumpf" turbine has now merged its identity in a type that will be described later on.

### The Compound Impulse Type.

(*a*) *Compounded for Pressure.*—The object of all compounding is to lower the peripheral velocity—to use wheels of a practical size having regard to the stresses to which they are subjected, and to dispense with gearing.

In this type there are therefore stages or steps by which the pressure drops; in fact, as many pressure stages as there are revolving wheels, successive expansions of the steam taking place in the fixed diaphragms through which it passes from admission to exhaust. The total number of stages depends on the steam admission pressure, the exhaust pressure, and the correct velocity of steam to give the best effect. The expansion of the steam is provided for by gradually increasing the area through fixed and running vanes. This may be effected by either lengthening the vanes themselves, keeping the peripheral width constant, or by keeping the length of vane constant and increasing the peripheral width, so that by the time the steam travels to the low pressure end it will be admitted all round the whole periphery of the vanes, forming a continuous belt of steam, instead of only being admitted at certain points of the periphery.

Two well-known turbines are illustrative of this class, the "Rateau" and the "Zoelly." In the **"Rateau"** type thin steel plate discs, flanged at the periphery for receiving the vanes, and slightly coned, form the revolving wheels. They are riveted to hubs which in turn are securely mounted on the shaft. A nickel steel shrouding surrounds the steel vanes. Ample clearances are given between wheels and casings. Each revolving wheel is placed between two fixed diaphragms. Therefore each wheel revolves in a cell or chamber of practically uniform pressure. There is no pressure drop across the wheels, and therefore no fine clearances are necessary. Professor Rateau gave the name "Multicellular" to this class of turbine. It should here be noted that in the "Rateau" and "Zoelly" types only one revolving wheel is used per cell, or per pressure stage. This distinguishes them from other types to be later described, Rateau being of opinion that the best steam economies are obtained with his method.

The fixed diaphragms are also made of two thin steel plates, riveted to castings at the hub and at the rim. The fixed vanes or distributor guide blades are the equivalent of the expanding nozzles in the "De Laval" type. To allow for the expansion of the steam, the openings may extend in width or peripherally; alternatively the depth of the vanes may be increased. A combination of both methods based upon practical expediency will generally be adopted. The number of fixed guide blades or vanes at the high pressure or admission end will be small, increasing towards the exhaust end until the complete circumference is occupied for the last wheels.

The diaphragms are fixed in grooves in the inside of the turbine casing which is made in halves on much the same lines as the modern "Parsons." The hubs of the diaphragms are bushed but clear for the shaft to revolve through them. Leakage from stage to stage or from cell to cell can therefore only occur at the hubs. Professor Rateau gives the leakage loss in a 1,500 b.h.p. turbine as 1½ per cent., and the friction of the wheels upon the steam or disc friction as 2½ per cent. It is conceivable that with large wheels the disc friction might be very considerable, and is a point to be taken into careful consideration in the design.

It will be seen that the absence of the necessary fine clearances will much simplify the problem of fine fitting and erection, and in the event of any distortion taking place, all that is likely to happen will be the wearing away of the anti-friction metal forming the bush on the hub, and any fouling of the running vanes is almost impossible. The peripheral speed of the "Rateau" may be taken at about 500 ft. per sec., or about one-third of the "De Laval." Although usually constructed in the horizontal form, with either separate or combined high and low pressure casings, a vertical type has been developed by the Oerlikon Co. of Zurich.

From two steam consumption tests taken at the manufacturers' works the following figures are taken.

Assuming the accuracy of the figures the last test leaves little to be desired in the

way of steam consumption per k.w.h., under the given conditions.

| K.W. | R.P.M. | Steam Press. | Vacuum. | Steam per K.W.H. |
|---|---|---|---|---|
| 1,000 | 1,500 | 165 | 25 | 22 |
| 475 | 2,500 | 210 | 26·3 | 19·8 |

The **"Zoelly"** turbine is akin to the "Rateau" as far as the principles underlying its action are concerned, but differs essentially in many details of construction. As in the case of the latter, the fall of pressure in the steam is confined to the distributing guide vanes in the fixed diaphragms; each revolving wheel therefore moves in a uniform pressure medium. All the kinetic energy developed in each stage is utilised in one wheel only, as in the "Rateau," but unlike the "Curtis" in this respect.

The turbine is of the horizontal form, and in the later types comprises one casing only for all the expansions, which is divided horizontally into two halves like the "Parsons." The construction of the wheels constitutes a very fine piece of mechanical work. Forged in one piece, with the boss of "Siemens-Martin" steel, they are turned and polished all over. Nickel steel blades carefully polished to reduce friction of the steam have their inner ends so shaped as to dovetail into a specially turned groove in the periphery of the wheel, the whole being backed by another grooved lip of forged steel which is bolted and riveted to the wheel.

The thickness of the latter, and also of the blades' tapers, the cross section decreasing from the hub to the rim give a spoke-like formation. Between the blades are spaced accurately cut distance pieces. After assembling the wheels on the shaft to the number required, the whole rotor is carefully balanced. It is claimed that by the methods of construction adopted the stresses due to centrifugal force are reduced to a minimum. Further, that the vanes are stronger than those of uniform section to resist the impulse of the steam. For a wheel of given diameter the working depth of vane and speed of rotation may be therefore greater than for a turbine of the "Rateau" order. Consequently the number of pressure stages may be less. The fixed diaphragms are made in halves with a metal to metal joint between them, and let into grooves in the turbine casing.

The guide vanes of sheet steel are cast into the diaphragms. The boss of the running wheels being turned and polished, revolves inside the hub of the fixed diaphragm, which is grooved internally to reduce leakage to a minimum. Thus the stator, or stationary portion of the turbine, consists of a complete upper and lower half casing, with its complement of diaphragms, and this can readily be removed for inspection.

The largest size in which the "Zoelly" had been operated until the latter part of last year was 3,000 h.p., but quite recently two units of 5,000 k.w. each, equivalent to some 7,500 h.p. at normal rating, built at the works of Messrs. Escher Weiss, of Zurich, have been installed at the Secteur de l'Ouest, Paris, and the Rheinische-Westphalian Station, Essen.

The following test figures for steam consumption on a 400 k.w. unit may be taken as accurate:—

| Load. | R.P.M. | Steam Press. | Vacuum. | Super-heat. | Steam per K.W.H. |
|---|---|---|---|---|---|
| 400 k.w. | 3,200 | 160 | 26·6 | 122° F. | 18·7 |
| 400 k.w. | 3,200 | 160 | 26·6 | 212° F. | 17·6 |

A feature of this turbine is the extraordinarily low steam consumption that Zoelly obtains on the lower loads, the consumption per b.h.p. hour at half load being only slightly inferior to the results obtained at full load.

The **"Hamilton-Holzwarth"** turbine resembles the "Rateau" and "Zoelly" in that it has distinct wheels for each set of blades or vanes, but follows the lines of the "Parsons" in that the steam flows through the turbine in a continuous belt from end to end. The number of wheels employed are far in excess of those used by Rateau and Zoelly. The turbine is being manufactured in Hamilton, Ohio, U.S.A.

(*b*) *Compounded for Velocity.*—In this type of turbine the whole of the initial pressure of the steam is expanded and converted into kinetic energy in the first set of fixed guide vanes or nozzles as in the case of the "De Laval."

The high velocity, however, instead of being taken up by one single wheel is exhausted in stages by passing through several alternatively moving and fixed vanes. The number of stages will again depend on the admission and exhaust pressure, and the best pre-determined

velocity of steam for each stage; but in the case of the turbine "compounded for velocity," the total number will be remarkably small as compared with the previous type.

A moment's reflection will show that this must be the case.

Taking a practical case of steam expanded down from 160 lbs. pressure to an exhaust pressure of 3 lbs. corresponding to a velocity of some 3,700 ft. per second, assuming that the velocity of vane rotation be one-half that of the velocity of the steam, and that the figure for the former be 500 ft. per sec., the velocity of the impinging steam will be approximately 1,000 ft. per sec. Therefore the stages will be $\frac{3,700}{1,000}$ or barely four required.

Although attempts have been made from time to time to develop turbines on these lines, there is not much chance of the type surviving as their efficiency is low. Many inventors have worked at the problem of re-utilising the steam on the same wheel, thus dispensing with the necessity of providing more than one wheel. But this is only secured at the expense of the introduction of complicated fixed reversing nozzles and twisted arrangements all entailing loss of energy.

A Mr. Terry, of Hartlepool, U.S.A., has patented a turbine on these lines in which the steam is returned many times over to the same row of blades. Allusion has already been made earlier on in this paper to the compounding of the "Riedler-Stumpf" turbine, which practically brought this turbine under the "compound for velocity" type.

The **"Elektra"** steam turbine has been developed by the Gesellschaft für Elektrische Industrie of Karlsruhe on the lines indicated above. A single impulse wheel is used as in the "De Laval" type, but relatively low speed is obtained by utilising successive impingements of the steam against the one wheel. The peripheral speed of wheel is from 260 to 330 ft. per sec.

(*c*) *Compounded for Pressure and Velocity.*—We now come to a type that embodies the principles underlying the two previous examples, viz., a turbine which is compounded both for pressure and velocity, which one writer compares "to a triple or quadruple expansion reciprocating engine, in which the work may be said to be divided into three or more cylinders in which the respective pressure drop is brought about in one operation."

Each stage consists of a set of expanding nozzles, and two, or more, rows of moving blades alternating with fixed blades. Between each stage is fixed a diaphragm with expanding nozzles. The total expansion of the steam therefore takes place in stages in the successive expanding nozzles, the kinetic energy developed at each expansion being absorbed as it passes through the successive moving and fixed blades of each stage.

Probably the best known example of this class is the turbine manufactured under the **"Curtis"** patents by the G. E. Co. in the United States, the B. T. H. Co. at Rugby in this country, and the A. E. G. Co. in Berlin. For land installations, the "Curtis" turbine is manufactured to-day with a vertical shaft.

The number of stages and the number of wheels per stage are dependent upon the degree of expansion of the steam and the peripheral speed required. In the later designs there are at least four stages, sometimes five, with two revolving wheels and one fixed diaphragm per stage.

After the details of construction given for former types, it will not be necessary to say much of the "Curtis." The revolving wheels are of cast steel, turned all over. The vanes are up to the present milled out of the solid, with a continuous shrouding around their tips, and are bolted on to the periphery of the revolving wheels.

The action of the "Curtis" is as follows:—Steam leaving the first set of expanding nozzles is directed against the first set of revolving blades; passing outwards through the row of fixed blades it impinges against the second row of revolving blades, finally emerging in the space at the end of the first *stage*. Entering the second set of expanding nozzles in the fixed diaphragm a further expansion of the steam takes place prior to the second stage cycle of operations, and so on to the end of the fourth or fifth stage.

It is claimed for the "Curtis" that greater economy results from the fact that the steam is more effectively directed against the running wheels by the nozzles than by simply employing stationary intermediate fixed guide vans as in the "Rateau" and "Zoelly" types—a claim which independent tests do not appear to wholly substantiate. The peripheral speed of the vanes in a "Curtis" is from 325 to 400 ft. per second. A feature of the "Curtis" is the governing arrangement. The regulation of the steam is effected by the opening or closing of individual nozzles at the entrance of the first rotating wheel. The centrifugal governor is connected to an electrically controlled device which directs the current to a series of electro-magnets; these in turn operate

pilot valves, each of which open or close the main admission valves of the nozzles. By this method of control the steam is not in any case throttled down, and the full benefit of the admission pressure is carried through a wide range of loads.

As in the case of all impulse types, there is no appreciable drop in pressure across the running wheels, or, in other words, as there is a uniform density in each stage, no fine clearances are necessary in the "Curtis" between rotor and casings. In the latest designs of the 5,000 k.w. type, the minimum clearances for the four stages are given as follows:—1st stage, ·08 in.; 2nd stage, ·08 in.; 3rd stage, ·09 in.; 4th stage, ·12 in.

The adjustment of the clearance is effected by means of an adjusting screw under the footstep bearing of the vertical shaft.

The following steam consumptions are extracted from published data relating to sets of moderate output:—

| K.W. | R.P.M. | Steam Press. | Vacuum. | Superheat. | Steam per K.W.H. |
|---|---|---|---|---|---|
| 500 | 1,800 | 150 | 28·5 in. | 115° F. | 18·75 |
| 1,000 | 1,500 | 150 | 28·35 in. | 142° F. | 16·9 |
| 1,500 | 1,000 | 150 | 28 in. | — | 19·0 |
| 1,500 | 1,000 | 150 | 28 in. | 200° F. | 16·0 |
| 2,000 | 750 | 160 | 28·8 in. | 242° F. | 15·3 |

Speaking broadly, it may be said with an increase in the pressure of admission steam from 100 to 150 lbs., and from 150 to 200 lbs., there will be 10 per cent. and 2½ per cent. decrease in steam consumption respectively. With steam admission pressures of 150 lbs. per square inch a 25 per cent. increase in the vacuum will give 17 to 18 per cent. decrease in steam consumption, and *pro rata* decreases for corresponding increases. For adding the first 100° F. of superheat there will be an 8 per cent. decrease in steam consumption; by increasing the superheat from 100° F. to 200° F. there will be a further decrease in steam consumption of 8½ per cent., and the third 100° F. of superheat will effect a further decrease of some 9 per cent.

### The "A. E. G. Curtis."

As pointed out in the earlier part of this paper, the A. E. G. of Berlin were responsible for the introduction and manufacture of the "Riedler-Stumpf" turbine. Within the last few years, having acquired the rights for the "Curtis" patents, a distinctive type known as the "A. E. G. Curtis" has been evolved.

To commence with, this turbine is built on the horizontal pattern; it has in the majority of cases two pressure stages only against the four or five of the "B. T. H." type, and each pressure stage has two speed stages as in the case of the "B. T. H." The author understands that in the larger units now being built the number of stages will be increased. The method of operation in each case is similar. Governing on the throttle only has been adopted, and the arrangement is simple and effective. Somewhat higher peripheral speeds obtain in the "A. E. G." type, as might be imagined from the fact that fewer pressure stages are adopted. The revolving wheels, however, possess a high factor of safety.

The following figures for steam consumption are published by the A. E. G. Co.:—

| K.W. | R.P.M. | Steam Press. | Vacuum. | Superheat. | Steam per K.W.H. |
|---|---|---|---|---|---|
| 1,000 | 3,000 | 180 | 28·5 | 220° F. | 16·5 |
| 1,000 | 3,000 | 180 | 26·5 | 125° F. | 18·4 |

The above figures show very strikingly the importance of a high vacuum and high degree of superheat for this type of turbine.

### Reaction Turbine.

In this type the velocity of the steam is generated in the nozzle, or nozzles, fixed tangentially in the rotor, and the rotation is effected by a purely "Reaction" process as in the Barker Mill.

A compound turbine of this type would therefore consist of a number of Barker Mills mounted in series on a common shaft, each working in its own cell, or stage, with graduated pressure; in short it would be compounded for pressure.

Parsons in 1903 took out a patent on these lines. There are no practical examples of this type of turbine, nor does it appear likely that any developments will take place on account of the high peripheral speeds that must be attained.

### Combined Impulse and Reaction Types.

We now come to a consideration of the class of turbines commonly known as the "Reaction," but which in their operation combine the "Impulse" and "Reaction" properties. In a turbine of this class the expansion of the steam is provided for in a regular and continuous manner, and takes place in the rotating as well as the fixed vanes. The chief example of these is the "Parsons" turbine; indeed up to quite a

recent time it may almost be said that the development of turbine engineering is connected with the name of Parsons.

In the **"Parsons"** type stationary deflecting or guide vanes direct the steam against the blades of the running wheel. In the stationary vanes the whole of the energy of the steam is not converted into kinetic energy, so that on emerging from the guide vanes the energy of the steam is only partially kinetic. That part which is kinetic is utilised in imparting energy to the moving vanes as in an ordinary impulse turbine. The portion of the steam emerging from the stationary vanes which is not kinetic expands in the moving vanes, and by this process of expansion further helps to drive them forward. There is therefore a combined effort—partly impulse, partly reactive.

The "Parsons" type is built with an enormous number of fixed vanes alternating with a corresponding number of movable vanes, which latter are fixed to the periphery of a rotating drum. There are therefore many stages, and whereas in the "De Laval" type the steam is expanded down in the nozzles to atmospheric or condenser pressure, with the result that the wheel runs in a more or less uniform density, the "Parsons" turbine, on the other hand, rotates in a high density at the steam admission end and a very low density indeed at the exhaust or condenser end.

Three things follow from this:—

(1) There is more friction of the wheel against its medium on account of the higher density, which may or may not be negligible. (2) There is an end pressure acting on the turbine in the direction of the steam flow which must be counteracted by "balance pistons." (3) There will be a leakage of steam across the rotating blades from one medium to another medium unless fine clearances are adopted.

In the modern type, all radial flow arrangements have been abandoned in favour of the parallel flow, the double flow self-balanced by the single flow balanced by dummy or balance pistons.

The turbine rotor consists of a long steel drum stepped up to varying diameters into which are shrunk and pinned the rotating shaft ends. Around the periphery are turned dovetailed grooves into which are expanded the vanes. The vanes are put in singly; next to a vane comes a wedge of brass, and the vanes and wedges are thoroughly caulked into the approximate six degrees dovetail. The vanes or blades thus inserted around the periphery are laced through by a wire of circular or other section. Messrs. Brown, Boveri to-day use a circular wire, and Messrs. Parsons a rectangular section brazed into notches cut in one edge of each blade.

When assembled, the stationary vanes are sandwiched in between rows of moving vanes. To give some idea of the number of vanes used, it may be stated that in a 750 k.w. turbine there would be no less than 15,000 revolving vanes, and a like number of stationary ones, a total of 30,000 in all. The increase in the diameter of the rotor drum is also followed by an increase in the radial depth of both vanes to provide for the expansion of the steam.

The material used for the vanes is more or less the manufacturer's secret, or, at least, they would have you infer so. It will suffice to say that brass, steel, cupronickel, and many alloys have been used.

The chief consideration underlying the employment of the many stages in the "Parsons" type is that it allows of a reduction of the speed of the turbine; the peripheral speed even in the largest sets rarely exceeds 400 ft. per second. The steam is admitted at the high pressure end, and passes along parallel to but spirally round the shaft in its flow through the fixed and movable vanes to the exhaust pipe.

For dealing with overloads, a bye-pass valve will admit high pressure steam into the intermediate stage. For balancing the end thrust, passages are left in the stationary casing, which communicate the steam from the various stages to the balance pistons. In the modern designs external pipes are frequently used to effect the same purpose, the area of the balance pistons being so proportioned as to enable the steam acting on the exposed area to equalise the thrust on the turbine rotating vanes.

The governing arrangements call for a word or two. The steam admission is not continuous, but consists of a series of gusts of steam at regular intervals, the duration of the gust being controlled by the governor varying with the load. It is claimed that this arrangement permits of a very sensitive regulation.

That the "Parsons" turbine is very economical as regards steam consumption has been amply demonstrated in practice, none more so, as the figures given below will testify.

The results of tests made to determine the effect of varying admission steam pressures, vacua and superheat, are of considerable interest, and as regards the first shows a marked divergence from the results obtained from impulse turbines.

Tests taken on a 3,000 k.w. "Parsons-Brown Boveri" set show that on full load

there was a decrease of only 5 per cent. in steam consumption for a 40 per cent. increase in steam admission pressure. At about half load no economy could be shown for the increase in steam pressure, and on low loads the steam consumption was actually greater for the higher pressure.

The result of this and other tests goes to show that there is little or no economy to be obtained on full load by increasing the steam admission pressure; on the contrary, for lower loads there may be a distinct loss.

The first proposition is therefore that the steam economy is independent of the admission pressure. The second proposition is that a decrease of steam consumption will follow an increase of vacuum, such percentage decrease being greater the higher the vacua obtained. For example, increasing the vacuum from 25 in. to 26 in. will result in a decrease of some 3 to 4 per cent., an increase from 26 in. to 27 in. some 4 to 5 per cent., and from 27 to 28 in. some 6 to 7 per cent. The figures hold good for full load only, for anything below this load they would require to be considerably increased.

The third proposition is that between 60° F. and 100° F. the decrease in steam consumption is fairly proportionate to the increased superheat. Below the former figure the decrease in steam consumption is greater than the increase in superheat and *vice versa*.

The following figures for average full load and half load steam consumption for turbines of moderate output of the "Parsons" type with a 26 in. vacuum and 122° F. superheat are extracted:—

| Output. | Lbs. per K.W. Hour. | |
|---|---|---|
| | Full Load. | Half Load. |
| 250 k.w. | 23 | 28·2 |
| 500 k.w. | 20·5 | 25 |
| 1,000 k.w. | 19 | 22·75 |
| 2,000 k.w. | 17·5 | 21 |

The guaranteed steam consumption for the new 6,000 k.w. "Willans-Parsons" set for Stuart Street, Manchester, with a 190 lb. steam pressure, a 27 in. vacuum and a superheat of 100° F. is 15·85 lbs. per k.w.h. on full load, corresponding to 10·75 lbs. per i.h.p. hour. At $\frac{3}{4}$ and $\frac{1}{2}$ loads the respective figures per k.w.h. are 16 lbs. and 16$\frac{3}{4}$ lbs.

Messrs. Willans & Robinson's design of the "Parsons," although identical in principle and in the chief features, nevertheless presents many points of interest, and many new mechanical features.

They may be classified as follows:—(1) Simplification of the governor gear, dispensing with the periodic steam gust admission and relying on an ordinary throttle valve controlled with a specially powerful centrifugal governor. (2) General accessibility to all the parts, so that the opening of the turbine is quite a simple matter. (3) Improved methods of balancing, dispensing with one of the "balance" pistons by a re-arrangement of the steam passages. This, together with the firms' special construction of the exhaust chamber, has shortened the length of the turbine rotor very materially. (4) A more mechanical and accurate system of blading. The roots of the vanes are all fixed in a foundation ring; the upper ends of the vanes are all fixed or shrouded with a ring of channel section. The blading for one complete periphery of the rotor is made up in two half rings, which are secured by special caulking strips in the dovetailed grooves. This blading construction has been adopted in the case of the turbines for the new Cunarders, and is unquestionably an improvement on the individual "blading" scheme. The author has suggested, and is adopting on the Manchester set, a locking strip for securing mechanical alignment of the two half rings, and this will also dispense with the necessity of interlacing the blades.

### The "Westinghouse" Turbine.

The Westinghouse Company, in the United States, have built with considerable success the straight "Parsons" type turbine. In this country, however, they have been manufacturing a turbine which differs essentially in constructional details. To commence with they have adopted the double-flow type, that is to say steam enters at the centre and flows outward both ways. There is an undoubted advantage as regards the elimination of balancing arrangements, and that a good mechanical design is obtained is not questioned, but as the complete turbine is composed of two turbines of one half the full capacity, there is the strong probability of inferior steam consumption results being obtained.

Mr. Parsons, as a result of careful experiments, discarded the double-flow type in 1890. To-day the Westinghouse Company are one of the very few firms—if not the only one—still adhering to the double-flow type. Steam then enters at the centre and passes both ways through a

series of nozzles and impulse blades, this operation being repeated until 75 per cent. of the kinetic energy of the steam has been expended. Then the steam still travelling outwards both ways passes through a series of fixed and movable blades on the "Parsons'" principle.

**Comparison of the Various Types.**

We have now considered at sufficient length the various classes of turbines as represented, say, by the four types—"De Laval," "Zoelly," "Curtis," and "Parsons."

For electrical or any other work requiring large units, the former need not be seriously considered.

Taking then the latter three, it may be stated that as regards the first two an efficiency (made up of nozzles and vane efficiency) of 70 per cent. may be attained in practice, although 65 per cent. is more likely to be the actual figure, with a possible efficiency of some 80 per cent. The chief losses are as follows:—(1) Condensation of steam. (2) Leakage from stage to stage. (3) Disc friction. (4) Eddy currents. (5) Vane friction.

The "Curtis" may have a slight advantage over the "Zoelly" in that whenever a leakage from stage to stage does take place the losses are collected at the end of the main stages, and the steam may be usefully expanded in the following stages. On the other hand, leakage troubles with the "Curtis" may become as serious as they are with the "Parsons" type unless there is a steam-tight joint between the stages. With the "Parsons" type a possible efficiency of 83 per cent. may be reached, but in practice 65 per cent. is rarely exceeded, owing to the serious "leakage" factor. From the point of possible efficiency therefore the "Parsons" type stands well, but it is thought that in actual conditions there is not sufficient difference to warrant a decided opinion on the respective types. The points in the mechanical construction have been brought out with, it is claimed, the balance of advantages in favour of the impulse type. On the score of steam consumption the "Parsons" type has little to fear.

The general trend of designers appears to be in the direction of making the "Curtis" type to approach more closely to the "Zoelly" by increasing the number of stages in the former. Professor Rateau in a paper read at Chicago in 1904 ventured the opinion that the type represented by the "Curtis" patents would finally resolve itself into the type represented by the "Rateau" and "Zoelly."

Whilst it cannot be gainsaid that the "Parsons" type possesses some manifest advantages, there appears to be an indication or movement, on the Continent at any rate, in favour of the compound impulse.

For large units at the present time the choice may be said to rest between the "Parsons" and "Curtis" types, "Zoelly" and "Westinghouse."

The chief drawback attached to the "Parsons" type of turbine is a mechanical one—viz., the risk or alleged risk of blade stripping.

Blade stripping may result from four causes:—(*a*) Inrush of water at starting up. (*b*) Distortion of the shaft, due to variable superheat, and consequent unequal expansion. (*c*) Variable vacuum, due to inefficiently designed condensing plant. (*d*) Whipping of the rotor shaft, due to the extreme length.

(*a*) This is a matter dependent largely on the human element, and with properly arranged steam-piping and adequate trapping arrangements may be entirely avoided.

(*b*) Apart from the economics of the question, it is not desirable to carry an excessive amount of superheat on the "Parsons" type of turbine. The author found on his visit to the Continent that almost every accident that had happened was traceable to the variableness of the superheat where excessive superheat was used. A moderate superheat of say not exceeding 125° F. is one that should probably be used with the "Parsons" type of turbine.

(*c*) This evil should not occur with properly designed condensing plants. Unfortunately there have been some bad examples of this, resulting in variable vacua, and consequent excessive end thrusts on the shaft, causing fouling of the blades in an end-on direction.

(*d*) This is almost entirely unknown now, especially in the "Willans" type, for the reason that they have been able to shorten the rotor shaft by the means mentioned in another part of this paper.

**Comparison of Turbines *v.* Piston Engines.**

A brief comparison of the turbine with the reciprocating piston engine may be usefully made.

The losses in a piston engine may be summed up under the following headings:—

1. Initial condensation. 2. Leakage past

valves. 3. Inability of the reciprocating engine to expand the steam completely down to condenser pressure. 4. Friction of bearings, &c.

*Initial Condensation.*—Live steam entering the cylinder of a piston engine comes in contact with the walls which have been cooled by contact with the exhaust steam. If the steam be therefore saturated, some must condense. A percentage may re-evaporate between the points of cut-off and release. Superheating the steam minimises, and in some cases may absolutely prevent, initial condensation.

In the case of a turbine, the steam comes in contact with metal surfaces which are practically at the same temperature as the steam itself, except just at starting up times. Initial condensation is therefore to all intents and purposes unknown in the case of the turbine.

*Expansion of the Steam.*—Steam turbines are able to expand the steam almost entirely down to the condenser pressure, and have therefore a decided advantage on this point. With a piston engine this is impracticable on account of the dimensions that would be required for the l.-p. cylinder.

As an example, with a pressure of ·5 lbs. abs. at the condenser, 1 lb. of steam would be equivalent in volume to 400 cub. ft. Obviously a l.-p. cylinder would require impossible dimensions to deal with this volume.

*Friction of Bearings, &c.*—The turbine scores over reciprocating engines also on this point, in that the frictional losses are reduced to a minimum by the absence of the many bearings, &c.

The question may therefore be fairly asked—How is it then, with all these points in favour of the turbine, it does not show far better economy in point of steam consumption than the piston engine?

The answer is to be found in the earlier part of this paper, in which the losses identical to a turbine proper are pointed out. The expansion of steam behind a piston is regular, smooth and quiet, while the expansion of the steam in a turbine used to give it kinetic energy with which to act on impulse blades is the reverse of a smooth and regular process. There is therefore a loss due to friction and eddies. There is, further, the loss incurred in the nozzles and guide vanes.

Friction and eddies will produce heat, but at the same time they lower the efficiency of the turbine. The greater part of this heat may be given up to the steam, but the loss resulting from the friction and eddies remains, and constitutes the chief losses in the steam turbine.

*Superheated Steam.*—The use of superheated steam improves both types of prime movers. In the case of a piston engine as a means of reducing initial condensation, in the case of a turbine as a means of reducing the fluid friction.

The following tables bring out the difference effected in such cases:—

TURBINES.*

| Degrees of Superheat, F. | 13 | 50 | 70 | 100 | 150 | 200 | 260 |
|---|---|---|---|---|---|---|---|
| Per cent. reduction of steam consumption. | 6·1 | 8·0 | 9·5 | 14·0 | 19·0 | 23·0 | 24·5 |

PISTON.*

| Degrees of Superheat, F. | 30 | 40 | 50 | 100 | 150 | 225 |
|---|---|---|---|---|---|---|
| Per cent. reduction of steam consumption. | 7·8 | 8·65 | 12·0 | 20·5 | 13·0 | 33·1 |

Comparing the efficiency of the turbine with the piston engine from the thermo-dynamic point of view, it may be frankly stated that the latter will show to be the more efficient.

The thermo-dynamic efficiency of the non-condensing engine is generally taken to be some 10 to 15 per cent. higher than the condensing engine on account of the practicability of the more complete expansion of the steam in the former case.

The difference is not present in the case of a non-condensing turbine. As a matter of fact, its efficiency is practically independent of the pressure range, at any rate in the "Parsons" type.

From this it is inferred that, considered as a *heat engine* only, the turbine is inferior to the extent of some 15 per cent.

From this, unbiassed writers on the subject have inferred that were it not for the fact that the efficiency of a piston engine falls off as the back pressure increases, a practical disadvantage which results from its inability to expand down to very low pressure for the reasons previously given, the turbine would not have made the strides it has done. This is quite apart from the

* Neilson, Cleveland Institute of Engineers.

equally important question of initial outlay, which to the engineer responsible for large electrical undertakings has so vital an influence on the costs at which energy can be produced.

The author does not consider that any advantage can be shown for the steam turbine as against the piston engine for sizes of 500 k.w. and under. On the other hand, given ample supplies of cooling water, for capacities above this figure, and especially for the larger units of 3,000—5,000 k.w., the turbine is pre-eminently the prime mover to be adopted for electrical work in our present state of engineering knowledge.

*Prime Costs.*—A word or two as to prime costs. It has been stated by two eminent writers (Stevens and Hobart) that "as yet the steam turbine is more expensive than the piston engine." The author entirely demurs to this statement; his experience with contracts placed during the past seven years shows conclusively that this is not the case.

The following figures are extracted:—

| Date. | Capacity. | Piston Engines. | Turbines. | Remarks. |
|---|---|---|---|---|
| 1900 & 1904 | 750 k.w. | £8 per k.w. | £4 4s. | Complete contract, including generators, piston engines, and condensers, £10 6s. per k.w. Do. for turbine, £8 7s. per k.w. |
| 1899 & 1901 | 1,800 k.w. | £6 per k.w. | £4 7s. per k.w. | Complete contract, including generators, piston engines, and condensers, £10 per k.w. Do. for turbine, £8 per k.w. |
| 1901 | 1,500 k.w. | £5 6s. per k.w. | — | — |
| 1902 | 3,750 k.w. | £6 13s. per k.w. | — | — |
| 1906 | 6,000 k.w. | — | £2 13s. per k.w. | — |

No figures for condensing plant or other accessories have been included in the Columns 2 and 3.

## Sir William Willcocks and the Raising of the Assuan Dam.

The raising of the Assuan Dam by 5 metres (16 ft. 5 in.) has been decided on, and has probably been already commenced. The high-water level of the reservoir will, on the completion of the additions, be raised 7 metres (23 ft.), and the capacity of the reservoir will thereby be increased from 1,000,000,000 to 2,300,000,000 cubic metres.

In the course of an interesting lecture before the Society of Arts on the subject of Irrigation in Egypt, Sir Hanbury Brown, K.C.M.G., stated that the decision to raise the Assuan Dam has been lately criticised by Sir William Willcocks* in a way which, he himself admitted, a diplomat would not have done. He did not know, when he delivered himself of his criticisms, that he was wrong in his facts. He was severe on the decision to raise the dam 7 metres, instead of 6 metres as he himself had proposed, and expressed himself in these words:—"I have tried in vain to fathom the reasons which led the late Sir Benjamin Baker, as Consulting Engineer to the Government, to advise the raising of the dam by 7 metres, when he had resisted its being raised by 6. He might have recommended its being raised by 5 metres as something quite safe." It was by 5 metres that Sir Benjamin recommended that the dam should be raised, and not by 7: it was the high-water-level of the reservoir that would be raised by 7 metres. Sir W. Willcocks's not too delicately worded criticisms of Sir B. Baker, therefore, rested on as faulty foundations as the Delta Barrage originally did. The speaker thought it only right that he, being a member of the Institution of Civil Engineers, should take this opportunity of speaking in defence of one of the most esteemed in his profession, now that he could do it for himself; not on the principle of *de mortuis nil nisi bonum*, but because there was no justification whatever for the unworthy suggestion that Sir Benjamin's recommendations concerning the raising of the Assuan Dam were influenced by any other consideration than the desire to give the best professional advice in his power to the Egyptian Government.

* Lectures delivered in Cairo to the Khedivial Geographical Society on 21st December, 1907, and 25th January, 1908.

## "Atlantic" Type Four-Cylinder Compound Locomotive, Danish State Railways.

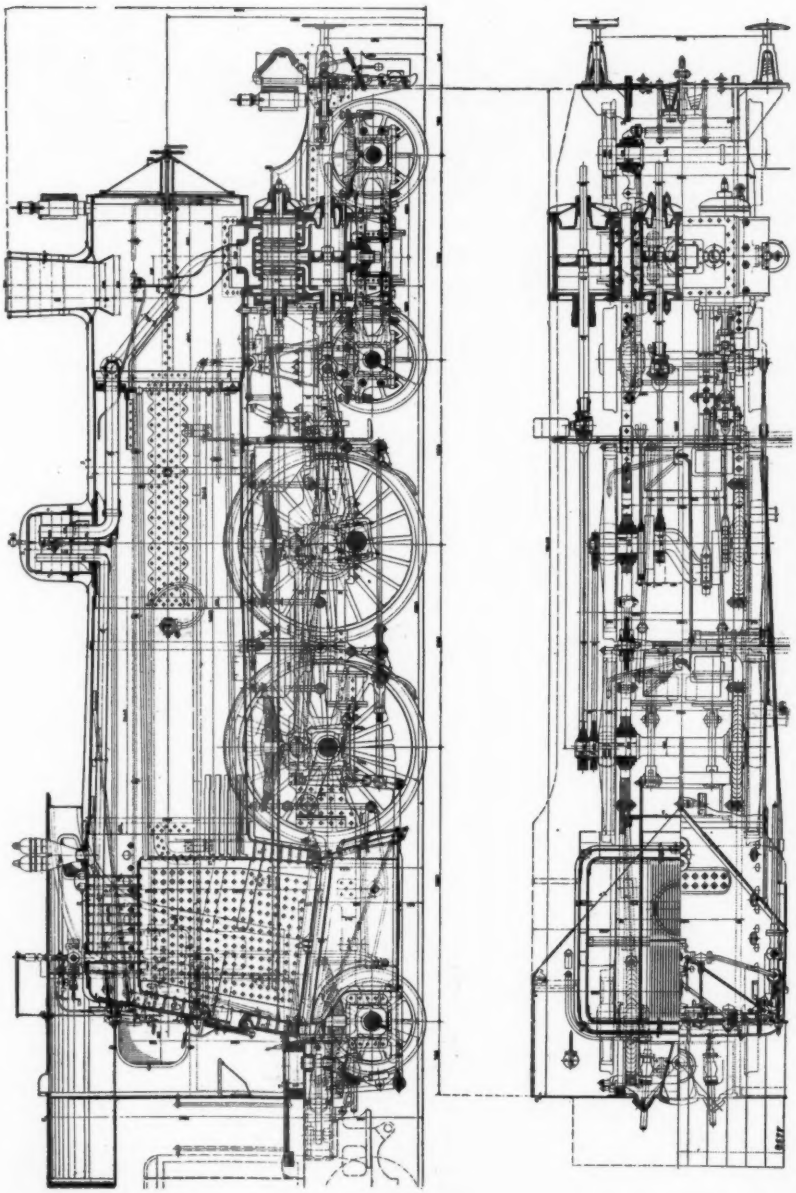
Towards the end of last year the Danish State Railways received delivery of some large four-cylinder compound locomotives of the 4-4-2, or "Atlantic" type built by the Hannoversche Maschinenbau Actien-Gesellschaft, by whose courtesy we illustrate herewith, by means of a photographic reproduction and detailed drawings, one of the new engines. The design represents an advance in every respect upon previous locomotive standards in Denmark, and the engines are of considerably greater size and power than any of those which have preceded them on the same system of railways. The four compound cylinders are arranged in line below the smokebox, with the high-pressure ones between the frames and the low-pressure outside of them. The inside cylinders drive the crank-axle of the leading coupled wheels while the low-pressure connecting rods act on crank pins in the rear pair. The crank axle is of the oblique or *Z* type, with single disc pattern crank webs, the axle being made of nickel steel, and to rectangular section between the crank pins. Steam is distributed to the four cylinders by means of two large piston valves, each of which is for double admission and acts for the inside and outside cylinder on the same side of the engine. The two-valve gears, of the Walschaert's pattern, are driven off the high-pressure (crank) axle by single eccentrics placed between the crank and the frame, and a rocking shaft is employed for transferring the motion from the lower to the higher plane, the piston valve working above and between the cylinders as shown in the cross sectional drawing.

The two cranks on each side are set opposite one another, *i.e.*, 180 deg., and at right angles, 90 deg. to those on the opposite side, this being the arrangement usually adopted for balanced four-cylinder locomotives in modern practice.

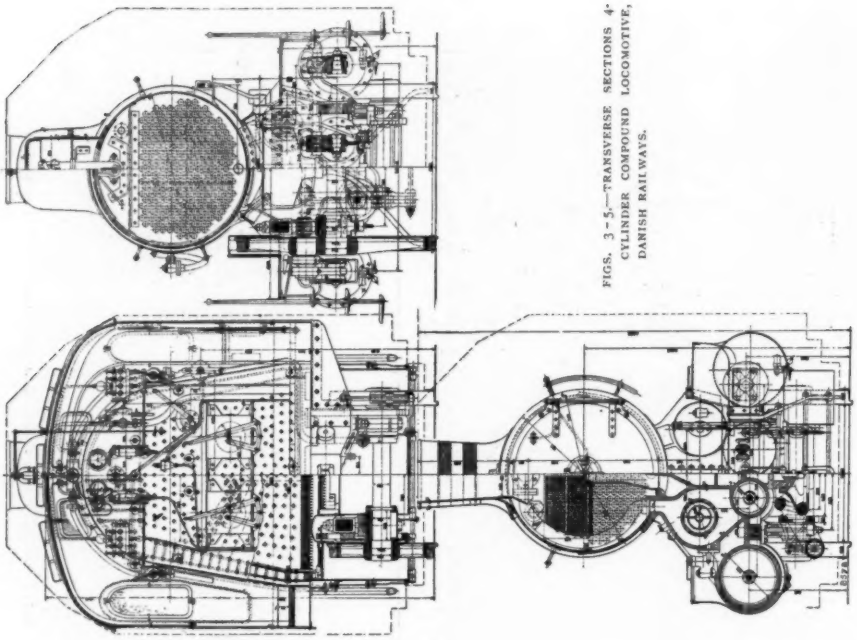
The boiler barrel is built of steel in two telescopic rings, of which the one next the firebox is of coned shape spreading out to give a much larger cross sectional area near the fire than at any other point in its length. The firebox is of the wide type with sloping back plate and inclined grate. A deep ash pan with dampers at the forward end only is provided. The safety valves, which are of the "pop" type, are located over the front end of the firebox, and the only other boiler mounting is the steam dome, which is affixed to the forward ring of the boiler barrel. The smokebox is of considerable length and is fitted with a deflector arrangement for minimising spark throwing. The smokebox door is of conical formation, as is also the front of the driver's cab, for the purpose of reducing the effect of wind resistance. Inside framing is employed for the engine throughout, the main frames being mostly of the bar pattern employed almost exclusively in American locomotive practice.

The springs of the coupled wheels are connected to those of the trailing carrying wheels below the footplate by a system of equalising beams, and brake gear is applied to all the wheels of both engine and tender. An hydraulic brake operating cylinder is carried in a vertical position at the front end of the tender, and there are two horizontal cylinders between the engine frames in front of the rear coupled axle which actuate, through a system of links and levers, the brake blocks for both pairs of coupled wheels and also for the trailing wheels. The bogie has a self-contained brake apparatus independent of the other gear.

The tender is carried upon eight wheels, but in place of the usual arrangement, in which two four-wheeled bogies are employed, all the axles are rigid. The frames are placed outside the wheels in the case of the tender, and the springs are compensate in pairs as seen in the photographic



FIGS. 1 AND 2.—LONGITUDINAL SECTION AND HALF PLANS, "ATLANTIC" TYPE, 4-CYLINDER COMPOUND LOCOMOTIVE, DANISH RAILWAYS.



FIGS. 3-5.—TRANSVERSE SECTIONS 4-CYLINDER COMPOUND LOCOMOTIVE, DANISH RAILWAYS.

reproduction. These locomotives are noteworthy apart from anything else, in that they have all the valve gearing carried inside the framing, thus giving to the engine that simplified appearance which, though customary in this country, is very unusually met with upon the Continent or, indeed, anywhere abroad.

The principal dimensions are given below :—

| | |
|---|---|
| Cylinders diameter H. P. ... ... ... | 13¾ in. |
| ,, ,, L.-P. ... ... ... | 22⅞ in. |
| Piston Stroke... ... ... ... ... | 23⅝ in. |
| Wheels, diameter, Bogie ... ... | 3 ft. 6 in. |
| ,, ,, Coupled ... ... | 6 ft. 6 in. |
| ,, ,, Trailing ... ... | 3 ft. 6 in. |
| Wheelbase, Rigid ... ... ... ... | 6 ft. 10⅜ in. |
| ,, Engine total ... ... ... | 29 ft. 4⅜ in. |
| Boiler, Height of centre above rail ... | 8 ft. 8½ in. |
| ,, Working pressure ... ... ... | 220 lbs. |
| Heating surface : tubes, 2,071 sq. ft.; fire-box, 130·25 sq. ft.—Total ... ... | 2201·30 sq. ft. |
| Grate Area ... ... ... ... ... | 34·75 sq. ft. |

In working order the engine weighs 66 tons without the tender, and of this 31½ tons is available for adhesion. The tender carries 4,620 gallons of water and 5¼ tons of coal, and in full working order weighs 50 tons, thus engine and tender together weigh 116 tons.

## The Pwll-y-Pant Viaduct, Barry Railway.*

The viaduct described is for a double line of railway, is 800 yards in length, and crosses the main line of the Rhymney Railway, the Rhymney Valley, and the river of that name, about ten miles north of Cardiff. It consists of eleven spans of steel lattice-girders, 170 ft. 11 in. in length, which rest on brick abutments, and ten intermediate piers, eight of these piers being over 100 ft. in height; and the viaduct terminates at its north and south ends with semicircular brick arches of 36 ft. span.

The nature of the foundations, the concrete and brickwork in the abutments, piers, and arches, and the steelwork of the girders, cross girders, decking and bearings having been referred to, the author describes the timber staging on which the girders forming three of the spans were erected and riveted, and then calls attention to the chief feature of interest in the work, namely, the special method adopted for the lifting, carrying forward, and subsequent launching of the

* Abstract of a paper read by A. L. Dickie, M.Inst.C.E., before the I.C.E.

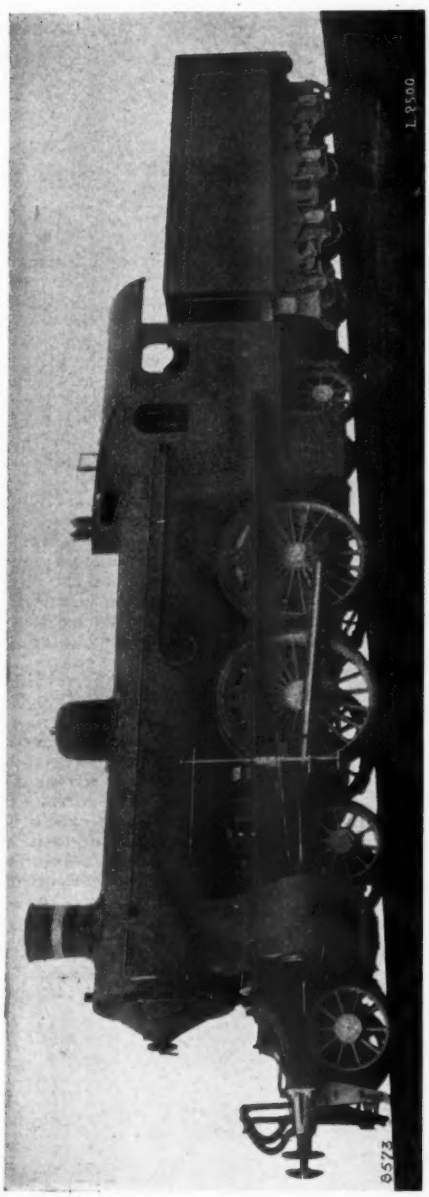



FIG. 6.—4-ATLANTIC TYPE, 4-CYLINDER COMPOUND LOCOMOTIVE, DANISH RAILWAYS.

girders of eight of the spans on to the piers in advance of those already erected.

With a viaduct such as that described, half a mile in length, and over 100 ft. in height above the valley and river which it crosses, the time required and the cost of erecting a staging from the ground-level for eleven spans would have been excessive; whereas the method described in this paper, besides proving very successful in its execution, was economical both in time and in cost. The author believes this to be the first instance in England of the erection of girders of such dimensions and weights by the method described.

The paper concludes with details of the weights of the girders and flooring, as well as of the rolling loads employed in testing the viaduct.

In an Appendix are given particulars of the progress of the brickwork, and of the erection, riveting and launching of the girders, the number of men employed, and the total cost.

## Improvements in Fish-plates and Joints of Railway Rails.

It is well known that the ordinary fish-plate joint, as at present in general use, while the simplest and cheapest that could be devised, yet is the weakest point in the permanent way as at present constructed.

Many attempts have been made to introduce a stronger and consequently improved joint, but in almost every case the designs have been complicated and costly, involving much alteration; consequently railway engineers have been practically driven to continue using the old style.

In order to improve the joint at a minimum cost, Mr. Marriott, M.Inst.C.E., resident engineer of the Midland & Great Northern Joint Railway, has patented a fish-plate which by only slightly altering the form of the old fish-plate makes a bridge or arch by which the rail is carried over the intervening space between the chairs adjacent to the joint, as shown in Fig. 7.

It will be seen that at each end of the fish-plate there is a foot which rests upon the adjacent chair, this

chair being provided with an extended table as a support for the fish-plate. This "inter-joint chair," as it is termed, which already has a table carrying the rail to the edge of the sleeper, was first introduced by Mr. Alexander Ross, M.Inst.C.E., chief engineer of the Great Northern Railway, and is used throughout the Great Northern system and the Midland & Great Northern Joint Line with highly satisfactory results. To suit the new fish-plate, it has only been necessary to widen this table

FIG. 7.

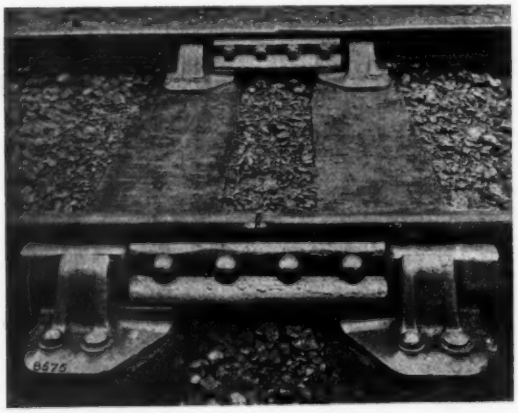


FIG. 8

sufficiently for the fish-plates to be supported on it (see Fig. 9).

Anything that tends to minimise the deflection at the joint must prolong the life of the rail and ensure smoother running and more comfortable travelling. The joint has been under observation on a short length of line for more than twelve months and has proved highly satisfactory (Fig. 8). The ends of the rails have been examined from time to time and the amount of wear is scarcely noticeable, showing that there is not so much deflection as in the ordinary joints adjacent, which show more flattening of the rail heads during the same period.

There is no fresh rust to be seen in the new joints between rail and fish-plate, as is so often seen at the ordinary joints. The fish-plate beds fair on to the chair and there has been no trouble from the sleeper tilting, as perhaps might have been expected. The new fish-plate is termed the "Bridge" fish-plate, and may be made in the form shown in Fig. 7, or as shown in Fig. 8.

In Fig. 7 the minimum amount of weight is obtained, but on the other hand, the manufacture is more difficult.

Fig. 8 being heavier, it is of course more costly, though when compared with the British standard fish-plate for 85-lb. rails, the extra cost works out at from 45 to 46 per cent. more, which is not a very serious item, as the cost of fish-plates only per mile is not high.

The additional cost for chairs is about 7 per cent.

Taking the cost of materials only for a single line at £2,000 per mile, the extra cost would work out at about 1 per cent.

Taking into consideration the enormous and increasing loads now passing over our permanent way, and the sums of money expended in costly and luxurious rolling stock, it cannot be said that an extra expenditure of 1 per cent. per mile to ensure a better joint is extravagant,

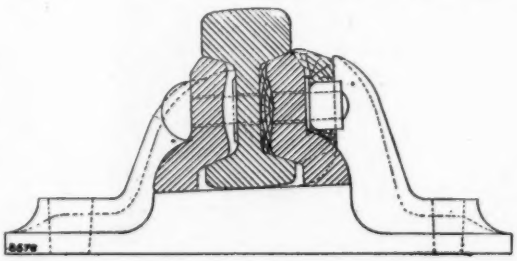


FIG. 9.

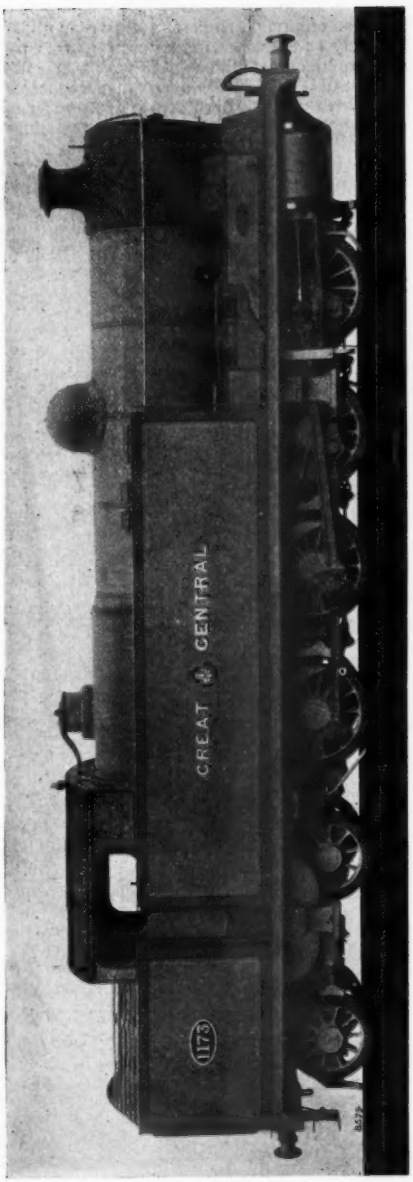



FIG. 10.—0-8-4 3-CYLINDER TANK ENGINE, GREAT CENTRAL RAILWAY.

as it must tend to a longer life all round.

## 0-8-4 Three Cylinder Shunting Tank Engine, Great Central Railway.

The powerful tank engine forming the subject of the accompanying illustration has been specially designed by Mr. John G. Robinson, chief mechanical engineer of the Great Central Railway Company, for sorting and marshalling goods and coal trains in the company's new concentration yard at Wath. The yard is made on the "hump" system, incoming trains being propelled up the "hump," at the top of which the wagons for the various sidings of the "gridiron" are detached and allowed to descend the incline on the other side by gravity. The maximum gradient in the yard is 1 in 109, and these engines are required to push trains of 70 loaded wagons weighing about 1,050 tons up this slope in order that they may be distributed. For this service high tractive power at a moderate speed is required, coupled with a regular turning moment so as to diminish as far as possible the tendency to slip, and ensure that the engine shall be ready to exert its maximum effort from any crank position. Working as it will do behind its train, and at the foot of an incline, it will always have the train pushing back on it, and will have no slack of buffers or couplings to take up to enable it to start. From these considerations it was decided to employ three cylinders, which gives a far more regular turning moment than either two or four, provided the cranks are at 120 degrees with each other. The maximum variation in full gear is only about 5 per cent. on either side of the mean, so that the engine will have the starting and non-slipping qualities of an electric locomotive. Owing to the very intermittent demand on the boiler it has not been necessary to provide any excessive grate or heating surface, and this has made it possible to make up the weight by ample water and coal capacity.

As is customary with the engines of the Great Central Railway, particular attention has been paid to the interchange ability of details with those of other engines. For example, the boiler is that used for the "Atlantic" express engines. The wheels, axles, axle-boxes, coupling and outside connecting rods, motion, &c., are exactly like those of the 8 wheels coupled mineral

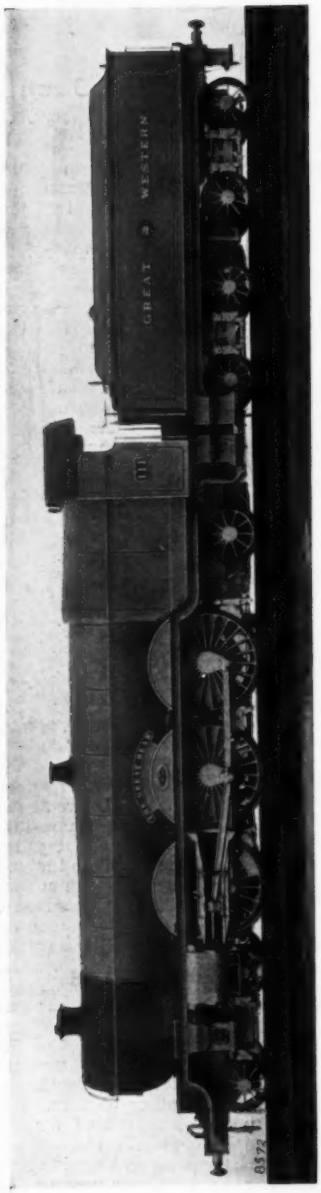



FIG 10.—"PACIFIC" TYPE EXPRESS LOCOMOTIVE, GREAT WESTERN RAILWAY.

Owing to the fact the March number was in the press before the photograph of "The Great Bear" was received from Swindon, we were unable to reproduce it with the description and outline drawing of the engine which appeared in that issue. It should be mentioned that the "Davies and Metcalfe" exhaust steam injector is fitted on this engine.

engines, and the inside motion is similar to that of the latest six-coupled goods engines.

The engine can exert a draw-bar pull of nearly 13 tons, and can maintain this pull up to 9 or 10 miles an hour. When it is remembered that about 40 tons represents the breaking strength of the average wagon drawbar of this country, it will be recognised that its power is as high as is either necessary or desirable. In order to facilitate quick handling the reversing is performed by a steam and cataract gear, and every wheel on the engine, including those of the bogie, is braked, the pressure being applied by steam, controlled by a valve worked either by hand, or in connection with the vacuum brake.

The following are a few leading dimensions:—

| | | |
|---|---|---|
| Cylinders (3) ... .. ... ... | | 18 in. dia. × 26 in. stroke |
| Wheels (8-coupled bogie) ... ... | | 4 ft. 8 in. dia.<br>3 ft 7 in. dia. |
| Tyres ... ... ... ... ... | | 3½ in thick. |
| Boiler: Length ... ... ... ... | | 15 ft. |
| Diameter ... ... ... | | 5 ft. |
| Firebox: Length ... ... ... | | 8 ft. 6 in. |
| Tubes (steel): Number ... ... | | 221 |
| Diameter ... ... | | 2 in. |
| Length ... ... ... | | 15 ft. 4⅞ in. |
| Heating surface: Firebox ... ... | | 153 sq. ft. |
| Tubes ... ... | | 1,778 sq. ft. |
| Total ... | | 1,931 sq. ft. |
| Grate area ... ... ... ... | | 26 sq. ft. |
| Working pressure ... ... ... | | 200 lbs. per sq. in. |
| Tank capacity ... ... ... ... | | 3,000 gallons |
| Bunker capacity... ... ... ... | | 4 tons |
| Drawbar pull up to 10 miles per hour | | 13 tons |
| | tons. | cwts. |
| Weight on coupled wheels fully loaded | 73 | 12 |
| ,, bogie ,, ,, | 22 | 19 |
| Total ... ... | 96 | 11 |
| Empty weight ... ... ... ... | 74 | 1 |
| | ft. | in. |
| Wheel base: Coupled ... ... ... | 17 | 1 |
| Bogie ... ... ... | 7 | 6 |
| | 30 | 8 |
| Length over buffers ... ... ... | 45 ft. | ½ in. |

## 4-4-0 type Express Locomotive, Glasgow and South Western Railway.

A new series of 4-4-0 type locomotive similar in general respects to the Nos. 8 and 240 classes which preceded it, but with a larger boiler to cope with modern traffic requirements, has lately been put into service on the Glasgow and South Western Railway. One of these machines is illustrated in Fig. 11. These were built to the designs of Mr. James Manson, locomotive

superintendent at the Company's works, Kilmarnock. The leading dimensions are:

Cylinders, 18½ in. diameter by 26 in. stroke.
Diameter of bogie wheels, 3 ft. 7½ in.
" of coupled wheels, 6 ft. 9½ in.
Coupled wheel base, 8 ft. 9 in.
Total wheel base, 21 ft. 8 in.
Heating surface—

| | | |
|---|---|---|
| Firebox ... | ... ... ... | 123 sq. ft. |
| Tubes ... | ... ... ... | 1,297 " |
| Total | ... ... ... | 1,420 " |

Grate area, 22 sq. ft.
Weight of engine in working order, 53 tons 3 cwts.
The tender has a capacity for 2,900 galls. of water and 5 tons of coal, and weighs in working order 35 tons 12 cwts.

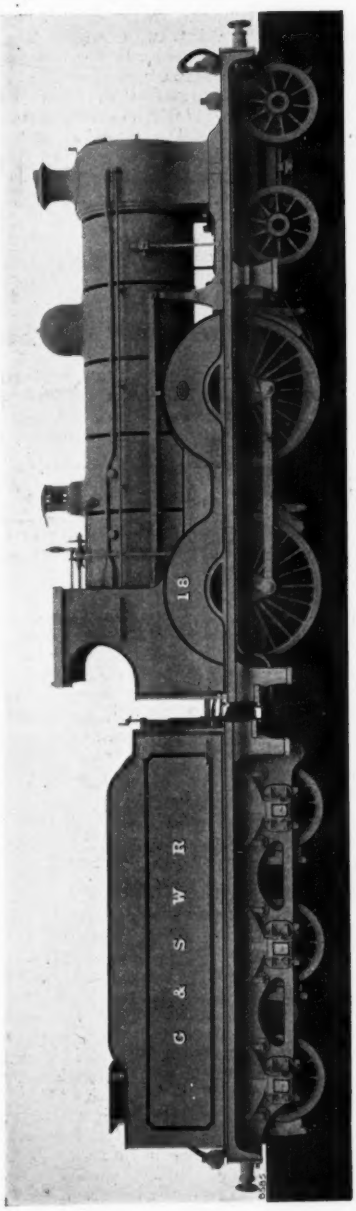



FIG. 11.—4-4-0 TYPE EXPRESS LOCOMOTIVE, GLASGOW AND SOUTH WESTERN RAILWAY.

## The New York Rapid-Transit Subway.*

The population of the city of New York is about 4,150,000, distributed among five boroughs. The railway described in this paper is confined chiefly to the borough and island of Manhattan, the most important district of the city. The railway has been constructed by and at the expense of the Municipality, under the jurisdiction of the Rapid Transit Commission, through two contracts with one company. These contracts provided that the company should construct the railways for a lump sum in each case, payable in cash by the city as the work progressed; that it should furnish all equipment, to be taken over by the city on an appraised value at the termination of the leases, and to operate the railways for 50 years with the renewal period of 25 years. The rental during the first period is the interest on the city's bonds issued for the construction, plus 1 per cent. per annum for a sinking-fund. For the second period the rental is to be fixed by arbitration.

The material through which the railway has been built is chiefly a mica-gneiss rock and sand.

The route begins at one of the suburban stations of the Long Island Railroad, in the borough of Brooklyn, passes under streets in that borough for 1½ miles, and thence in tubes under the East River, whose width at the point of crossing is nearly 1 mile; it then follows a central route under streets in Manhattan for about 8 miles, where the line forks, one branch continuing north, the other north-east to the upper part of the city in the borough of the Bronx, giving a total length of route of 25·7 miles.

It was in 1894 that the Rapid Transit

* Abstract of a paper by Wm. B. Parsons, M.Inst.C.E., read before the Institution of Civil Engineers.

Commission was appointed and the work projected; but for various reasons the latter was not begun until 1900. Contract No. 1, covering about 21 miles, was completed in 1904; and contract No. 2, executed at the close of 1902, and involving the slow work of subaqueous tunnelling, has recently been put in operation. The question of type involved much labour in consideration, great effort being made by many people and some newspapers to have New York follow the lead set by London in tube construction. The author, as chief engineer to the Commission, after a study of the tubes in operation and under construction in London, advised that the converse extreme principle in design be adopted, and that so far as possible the railway be of "subway" rather than tube type, and be kept as close to the surface as local conditions permitted.

In New York, the demand for additional transportation, especially for long distances, was so great that the two tracks were recognised as being too few to carry the traffic, and especially to give the required high speed. It was therefore decided to construct four tracks, parallel, and usually on the same level, over the central section, where the traffic would be the heaviest, on which trains could run all day in both directions. The outer tracks were to serve the local traffic, with about four stations to the mile, while the inner tracks were to carry the fast service, with stations at intervals averaging 1½ miles. On the sections where traffic would be less heavy, three tracks were projected, the central one to give an express service in the direction of maximum demand; that is, towards the commercial district in the morning, and from it in the evening. Of the total route, 10·2 miles have two tracks; 7·6 miles, three tracks; 7·6 miles, four or five tracks; 0·2 mile, eight tracks, a storage yard; and 0·1 mile, one track, a terminal loop.

To support the street roadway, a flat roof was adopted, consisting of transverse beams set at 5 ft. spacing. As the result of careful investigation, it was found to be more economical to support these beams on rows of columns between the tracks, without any longitudinal girder. Construction was also facilitated by such design, as the individual members were thus made light in weight, and were limited to few varieties. The roof beams at the sides rested on I beams in the walls, and wherever there was an upward hydrostatic pressure, transverse beams were embedded in the floor. There was thus formed a frame of steel members capable of taking all the stress. Between the beams was moulded concrete.

From the surface of the paving to the top of the roof the minimum distance is 30 in., governed by the yokes of the surface electric tramway. The height in the clear from rail-level to underside of roof is 13 ft., and the width per track is 12 ft. 6 in. The internal diameter of a tube of corresponding capacity would be 15 ft. 6 in. This accommodates a car similar to the one in use on the New York elevated system, and much larger than any car in the London tubes, except the Great Northern and City. The minimum depth from street to rail-level is 17 ft., and to platform about 13 ft. Every effort was made to attain this last dimension at stations.

In order to keep the subway dry, an envelope of water-proofing material was embedded in the concrete of floor, walls, and roof. This material was alternate layers of paper roofing-felt and carefully selected asphalt. This envelope was made continuous, and was protected from subsequent external injury by an external covering of concrete. This was found to work well against even a substantial hydrostatic pressure. Where, however, such pressure became considerable, layers of bricks, dipped in asphalt, were used instead. The concrete was mixed very fluid, in order to secure as tight work as possible, irrespective of the waterproofing. Its proportions were usually 1 part cement, 2 of sand, and 4 of gravel or fine broken stone, except where used in large masses, when the proportion of the aggregate was increased.

After the work had begun, a structure of reinforced concrete was designed instead of the beam construction, and has been largely used. The rows of columns between the tracks are retained, and, in order to economise space, such columns are of steel. A longitudinal truss of reinforced concrete connects the columns, while the roof and walls contain rods on the tension side. Wherever below the level of standing water, rods were embedded in the floor. Such construction, in practice, was found to be both cheaper and more expeditious than beam construction.

Although the basis of the design is a shallow subway, with a flat roof, and constructed by cut-and cover methods, there was no hesitation to depart from this type if conditions demanded or warranted such a course. There are 14·2 miles of cut-and-cover, of which 13 miles have a flat and 1·2 mile and arched roof, 3·9 miles of masonry-lined tunnels, 2·7 miles of iron tubes, and 6·6 miles in the open or on steel viaduct. The total mileage of types is greater than the route mileage, as some of the tunnels,

notably the tubes, are separate structures for each track. All kinds of construction are thus embraced in the New York railway. In building the tubes compressed air was used at as high a pressure as 40 lbs. per sq. in.

Stations for the local tracks, except in a few instances where island platforms were more convenient, have platforms on the outside with short direct stairways leading to the pavement. There are for each platform usually two exit and two entrance stairs. The express stations are served by island platforms, one between each pair of tracks, connected with each other and with the street pavements by an overhead bridge. At such stations passengers can transfer freely and without extra charge from local to express trains and *vice versâ*. Such transferring is done to an unexpected extent, the local trains acting as gatherers and distributors for the express trains. The express trains are scheduled to make about 30 miles per hour, and the locals 13 miles.

There are 58 stations, of which all but four are reached by stairs only, while of the four, three have lifts, and one a moving staircase working in both directions.

Junctions are arranged so that opposing tracks pass under and over, there being no level crossing. The sharpest curve where speed is possible has a radius of 458 ft., and the maximum gradient is 1 in 33, or less than 1 in 60 if accelerating is likely.

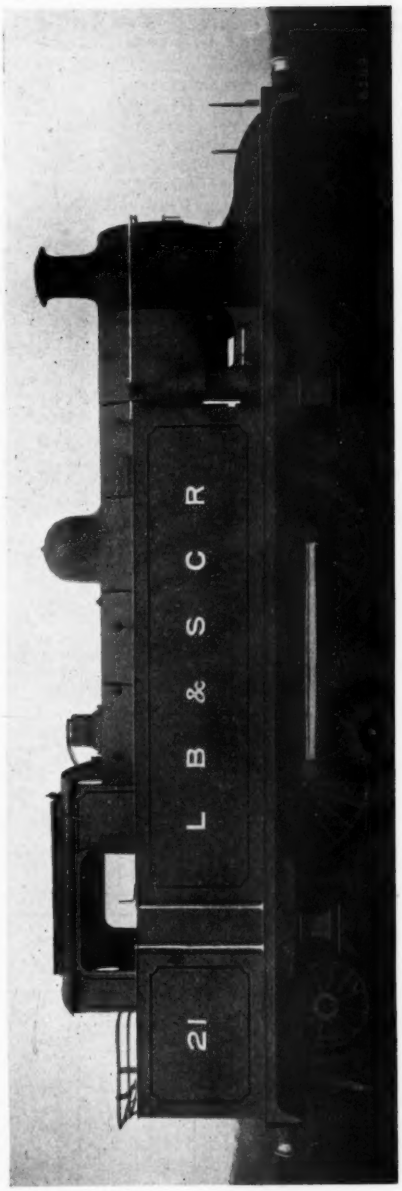
The express tracks are wholly, and the local tracks partly, protected by automatic block signals, with emergency automatic stops. The permanent way is of the usual American standard with 100 lb. rails.

The shallow subway required a very thorough reconstruction of the sub-surface structures, accomplished at times by drastic measures. The sewers required the most care, 17 miles of new sewers being built, varying in size from 12 in. pipes to 15 ft. diameter brick structures.

All materials were purchased after close inspection. Elaborate investigations were made into the quality of cement, and the physical properties of concrete, both plain and reinforced, and the effect of paint or other coating of the embedded rods. This was essential on account of the large quantity of concrete used, namely, 725,000 cubic yards, and 1,320,000 barrels of cement.

The cost of the railway, 25·7 miles long, with 76·3 miles of track, was about £10,000,000, exclusive of equipment, interest during construction, or easements; the equipment added about £5,000,000.

Results of operations have been very




4-4-2 TYPE TANK ENGINE, LONDON, BRIGHTON & SOUTH COAST RAILWAY.

gratifying. During the fiscal year ended June 30, 1907, on 21 miles, the line to Brooklyn not being open, over 166,000,000 passengers were carried. The current year is showing a considerable increase, exclusive of the Brooklyn traffic, which since Jan. 1, 1908, adds still further to the total. The fare is 5 cents (2½*d.*), regardless of distance.

The author is of the opinion, *inter alia*, that the cost of shallow construction does not exceed deep-tunnel construction, unless the former is burdened by heavy charges for vault easements; and that the success of the New York subway is due to the high-speed service and the convenient arrangement of the stations with their short direct means of access.

## 4-4-2 type Tank Engine, L.B. & S.C. Railway.

The vogue of the tank engine for short distance express and semi-express work still continues to gain in popularity, the most recent and not the least interesting contribution to this section of locomotive practice being provided by the L.B. & S.C. Railway. As will be seen from the accompanying photo reproduction, it is of the 4-4-2 type, with side tanks, and faintly suggests in appearance some of the side-tank engines of the Great Northern Company. The driving wheels, however, have the unusually large diameter for this type of engine of 6 ft. 9 in., which, together with the fact that the heating surface totals up to 1,623 sq. ft., signalise it as being well suited for fast traffic. The cylinders are 19 in. in diameter by 26 in. stroke, and are set at an inclination of 1 in 9½. The steam-distributing passages are arranged between the cylinders, the valves themselves, which are of the balanced "D" type, working underneath. The bogie centre is thus somewhat lower than usual. A combined hand and power gear is fitted for reversing, the former operating by means of a screw and used when no air pressure is available. The power apparatus consists of an air cylinder, the piston rod of which works in connection with the hand screw. The thread of the latter is cut to a large pitch to enable the piston of the air cylinder to work both screw and handle when air is admitted by the small air-pressure cock controlled by the driver. The leading end of the engine is carried on a four-wheeled bogie, and the trailing end on a two-wheel radial truck. A somewhat unusual feature is that apparatus is provided for passing a portion of the exhaust steam into the tanks. The warm water from the latter is

RUN OF THE 8.45 A.M. BRIGHTON TO LONDON EXPRESS, DRAWN BY THE NEW TANK ENGINE, NO. 21.

| Schedule Time. | Actual time. | Distance. | Station. | Remarks. |
|---|---|---|---|---|
| | | M. C. | | |
| 8.45 | 8.45 | — | Brighton. | |
| 8.56 | 8.56 | 7 6 | Hassocks. | |
| 8.59 | 8.59 | 9 15 | Burgess Hill. | |
| 9.0 | 9.0 | 9 61 | Keymer Junction. | |
| 9.5 | 9.4 | 12 71 | Hayward's Heath | |
| 9.10 | 9.8 | 16 63 | Balcombe. | Permanent way slack to 15 miles per hour over Bletchingley Bridge |
| 9.15 | 9.12 | 21 28 | Three Bridges ... | |
| 9.28 | 9.26 | 32 9 | Quarry. | |
| 9.39 | 9.39 | 40 30 | East Croydon. | |
| 9.45 | 9.46 | 45 8 | Forest Hill ... ... | Permanent way slack to 5 miles per hour at Bricklayer's Arms Junction. |
| 9.55 | 9.55 | 50 52 | London Bridge ... | |

RUN OF THE 11.0 A.M. VICTORIA TO BRIGHTON EXPRESS, JANUARY 19TH, 1908, DRAWN BY THE NEW TANK ENGINE, NO. 21.

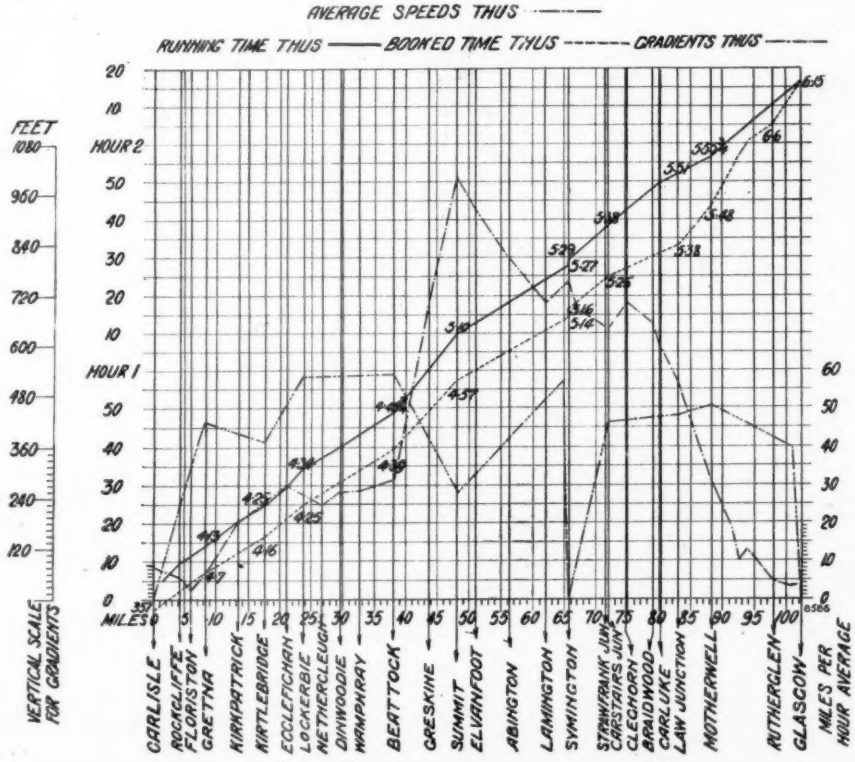
| Schedule Time. | Actual Time. | Distance. | Station. | Remarks. |
|---|---|---|---|---|
| | | M. C. | | |
| 11.0 | 11.0 | — | Victoria. | |
| 11.5 | 11.5 | 2 58 | Clapham Junction | Permanent way slack, 10 miles per hour. |
| 11.9 | 11.8 | 4 55 | Balham Junction. | |
| 11.16 | 11.13 | 10 43 | East Croydon ... | Permanent way slack at Stoat's Nest, 10 miles per hour. |
| 11.25 | 11.24 | 18 64 | Quarry ... .. | |
| 11.37 | 11.34 | 29 45 | Three Bridges ... | Permanent way slack to 15 miles per hour over Bletchingley Bridge. |
| 11.49 | 11.45 | 41 12 | Keymer Junction. | |
| 12.0 | 11.55 | 50 73 | Brighton. | |

fed to pumps through float pipes. Two pumps are fitted; also an injector. The weight available for adhesion is 38 tons, and the total weight fully loaded is 73 tons.

The following are the principal dimensions :—

| | |
|---|---|
| Cylinders, diameter and stroke ... ... | 19 in. by 26 in. |
| ,, width and length of steam ports ... ... ... ... | 1½ in. by 17 in. |
| ,, width and length of exhaust ports ... ... ... ... | 3½ in. by 17 in. |
| ,, travel of valve ... ... .. ... | 3 1/16 in. |
| ,, lap ,, ... ... ... ... | 1 in. |
| ,, lead ,, ... ... ... ... | 1/8 in. |
| Wheels, bogie, diameter ... ... ... | ... 3 ft. 6 in. |
| ,, driving ,, ... ... ... | ... 6 ft. 9 in. |
| ,, trailing ,, ... ... ... | ... 6 ft. 9 in. |
| ,, radial ,, ... ... ... | ... 4 ft. 0 in. |
| Wheel base, bogie .. ... ... | ... 6 ft. 3 in. |
| ,, bogie centre to driving ... | .. 10 ft. 5 in. |
| ,, driving to trailing ... .. | ... 8 ft. 9 in. |
| ,, trailing to radial ... ... | ... 8 ft. 6 in. |
| ,, Total ... ... ... | 30 ft. 11 in. |
| Total length over buffers ... ... ... | ...40 ft. 8 in. |
| Boiler, largest external diameter... ... | ... 4 ft. 10 in. |
| Boiler, length ... ... ... ... ... | 10 ft. 9 7/8 in. |
| ,, centre from rail ... ... ... | ... 8 ft. 4 in. |
| Firebox, length outside ... .. ... | ... 7 ft. 7 in. |
| ,, length inside ... ... ... | 6 ft. 10½ in. |
| ,, breadth inside .. ... ... | 3 ft. 4 1/16 in. |
| Tubes, length between tube plates ... | 11 ft. 2 5/16 in. |
| ,, diameter ... ... ... ... ... | 1 5/8 in. |
| ,, number ... ... ... .. .. | ... 315 |
| Heating surface, firebox ... ... ... | ... 126 sq. ft. |
| ,, ,, tubes ... ... ... | 1,499 ,, |
| ,, ,, total ... ... ... | 1,623 ,, |
| Grate area ... ... ... ... ... | ... 24 ,, |
| Steam pressure ... ... ... | 180 lbs. per sq. in |
| Weight on bogie wheels (Fully loaded) | 19 tons 10 cwts. |
| ,, driving wheels (Fully loaded) | 19 tons 0 cwts. |
| ,, trailing wheels (Fully loaded) | 19 tons 0 cwts. |
| ,, radial wheels (Fully loaded) | 15 tons 10 cwts. |
| ,, total (Fully loaded) | 73 tons 0 cwts. |
| Weight of fuel carried ... ... ... | ... 3 tons. |
| Water capacity ... ... ... ... | ...2,110 gails. |

The design is by Mr. Earle Marsh, locomotive engineer to the Brighton Company, and we understand that he has six others of the type in course of construction. These, however, are to be fitted with




RUNNING OF THE 10 A.M. MORNING CORRIDOR TRAIN, EUSTON TO GLASGOW.

Carlisle to Glasgow :—Engine, 907. Number of Vehicles, 9. Number of Axles, 38.

piston valves, superheaters and larger cylinders

As an example of the work that is being accomplished by No. 21, we give particulars of two runs made in regular work by the engine. The loads behind the tender were respectively 359 tons and 241 tons, and in the case of the first run the train would have arrived at London Bridge five minutes earlier but for a succession of signal checks from Quarry to London Bridge.

## Everyday Work of Leading British Locomotives.

II.—THE CALEDONIAN RAILWAY.

In selecting typical runs on the Caledonian, we will first follow the 10 a.m. ex Euston, morning corridor Scotch express, which continues its journey north of Carlisle on the Caledonian system. With the liberal timing of 138 mins. for the 102 miles 25 chains separating Carlisle and Glasgow (including a 2 min. stop at Symington) the running of this train would appear to call for no particular comment. There are, in fact, two others, the 5.45 a.m. and the 8.57 p.m. afternoon corridor, whose timings are 123 and 125 mins. respectively, the latter, however, including a 2 min. stop at Strawfrank Junction. In taking these timings into consideration, it should not be forgotten that the Caledonian is not an ideal road for express work with heavy loads, involving as it does the Beattock climb of 10 miles at 1 in 88, 80 and 75, and numerous curves and junctions between Strawfrank Junction and Glasgow, which prohibit very high speeds being attained.

On the run in question, the load of 9 coaches, totalling 38 axles, was taken by No. 907, one of the "Cardean" class, the type introduced by Mr. McIntosh in 1905 for the "Grampian" corridor express services. They are of the six-coupled type, with wheels 6 ft. 6 in. diam. and a 4 wheeled leading bogie. Cylinders are 20 in. by 26 in., grate area 26 sq. ft., adhesion weight 54 tons 10 cwt., and steam pressure 200 lbs.

The departure from Carlisle was at 4 hr. 2½ min. or 5½ min. late, the run to Symington 66 miles 69 chains occupying 1 hr. 25¼ min. or 8 min. above the schedule time allowance. Gretna, 8½ min., was passed in 11 min. 5 sec., and Kirtlebridge 16½ miles in 22 min. 5 sec., a slack to a standstill outside Gretna accounting for at least 2 mins. From Kirtlebridge to Lockerbie 9 miles 6 chains, the time improved to 9 min. 25 sec., and Beattock—13 miles 75 chains from Lockerbie—was passed in 14 min. 5 sec. The climb to the summit occupied 21 min. 20 sec., speed falling momentarily to 28 miles per hour, and a careful run down—the speed at no time exceeding 69—brought the train to Symington at 5 h. 29¾ min. or 15¾ min. late. From this place to Glasgow 35 miles 16 chains the schedule allowance is 59 min. for the reason above mentioned viz., the numerous curves and junctions encountered. The run in question was, however, made in 47 min. 20 secs., so that the arrival time at Glasgow was only 2 min. beyond schedule. Beyond this acceleration and the run from Lockerbie to Beattock, there was nothing exceptional to note as the ascent to the summit was not a good one. Further details of the run may be gathered from the accompanying diagram in which are plotted running and booked times, *average* speeds and gradients. The Glasgow, Perth and Aberdeen service will be dealt with next month.

### BOOK REVIEW.

**Steel Works Analysis.** By J. O. ARNOLD and F. IBBOTSON, 3rd edition, pp. 468 + XIV. (London: Whittaker & Co.) Price **10s. 6d.**

Professor Arnold's "Steel Works Analysis" has long held a recognised position in the literature of analytical chemistry. The characteristic feature of the work has been that of reliability, and the methods given are, in the language of the laboratory, workable and accurate. Reliability and accuracy are again the leading features of the last edition, and the methods given can with perfect justice be described as up-to-date. Since the appearance of the first edition, the metallurgy of steel has undergone many changes, and from the analyst's point of view the most important are the range of special elements and the high speed steels. These are well provided for in this latest edition, and in addition to the usual range of special elements methods are given for the estimation of vanadium, titanium and tantalum. An admirable chapter is devoted to the analysis of high speed steels, whilst the methods for the analysis of the wide range of ferro alloys are fully given. Other sections deal with the analysis of ores and pig-iron; refractory materials and fuels, brass and bronze, the examination of boiler waters and practically all the materials entering the steel works laboratory are catered for.

Personal tests of the methods given in the book lead to the conclusion that no better or more reliable guide could be offered to the works chemist.

# GENERAL REVIEW

LEADING ARTICLES OF THE MONTH—CURRENT EVENTS—TECHNICAL INFORMATION FROM ALL SOURCES

**The Treatment and Formation of Road Surfaces.**—In introducing the subject at a recent meeting of the Society of Engineers, Mr. A. J. Metcalfe referred briefly to motor-car construction, how it should be amended to mitigate the dust nuisance, then indicated several of the difficulties retarding the improvement of road surfaces, the intolerable conditions caused by dust, and the unsuitability of present-day roads for present-day needs.

The Roads Improvements Association's recent tests and trials were discussed, and a short description of the machines competing and materials used were noticed, together with the Judge's awards and remarks.

Materials and methods generally used and adopted were next considered under three principal heads, viz.: (1) Treatment by spraying of existing surfaces; (2) Coating with ordinary materials, and *afterwards* using a preservative or bituminous binder; (3) Coating with materials *previously* treated with a preservative or bituminous binder.

Under the first head the author discussed (*a*) *palliatives*, such as westrumite, akonia, calcium chloride; (*b*) preparations *partly* composed of tar or oil, such as crempoid, ermenite, hahnite, pulvicide and emulsifix; and (*c*) preparations *chiefly* composed of tar, such as tar compo, marbit, dustabato, solidified tar, oil of tar, and tarvia, and a short description of each mixture or material was given, together with their respective properties, actions, methods of application, cost, &c.

Under the second head, materials and methods were briefly noticed. The matrix or "Gladwell" system was discussed, and copious extracts from Mr. Gladwell's specification were read on foundations, preparing of matrix or binder, laying of matrix and aggregate, rolling, and surface scaling. The cost of this system was also estimated.

The materials and methods used under the third head were next indicated, limestone being taken as an example. Attention was drawn to the treatment of the roadway, the materials, shaping camber, suitable rollers, &c. Ironstone slag and granite were also noticed. Tarmac and its method of preparation were dealt with, and the author's opinion was given as to the suitability of this kind of road surface for heavy as well as light traffic.

In conclusion, the author maintained that the chief hindrance to the improvement of road surfaces was a financial one.

**Shaft-Sinking at the Horden Colliery, South-East Durham.*** — The south-eastern portion of the Durham coalfield is covered unconformably by the magnesian limestone and so-called yellow sands of the Permian epoch, and it is the large volumes of fresh and brackish water encountered in sinking through these measures that constitute the chief cost and difficulty in the winning of coal in this area.

The "Horden Collieries, Limited," was formed in 1900 to win and work about 18,000 acres of coal in the south-east portion of the county, half the area being under-sea coal.

The scheme for developing this coal-property was to open two new collieries adjacent to the sea-coast, at Horden and Hesleden respectively, and to re-open and equip Shotton and Castle Eden Collieries, with the object of ultimately producing 10,000 tons of coal per day. Half the scheme has now been completed, and this paper has reference mainly to the shaft-sinking operations at Horden.

Having in mind the possible legislative interference with the hours of underground labour, it was decided to sink three shafts—two 20 ft. and one 17 ft. in finished diameter. It was also decided to purchase eight sets of common bucket pumps, each working-barrel to be 30 ins. in internal diameter, and each set 50 fathoms in length; to adapt two of the proposed winding-engines into four temporary geared pumping-engines; and to couple two sets of pumps on to each.

Taking advantage of a difference of level of about 200 ft. between high water mark and the surface of the shafts, a water-delivery drift was driven from the sea-coast a distance of about

* Abstract of a paper by J. J. Prest, M.Inst.C.E., read before the I.C.E.

600 yards, cutting the shafts at a point about 30 fathoms below the surface. This drift not only enabled the water to be delivered from the pumps at a point 30 fathoms below the surface, whence it gravitated to the sea, but also enabled the coal measures to be reached by means of a single high- and low-lift set of balanced pumps on each pumping engine.

Each shaft was equipped with a thirty-ton main crab-engine, sinking-engine, and jack-engine, and each pair of pumps was suspended by 5 in. diameter plough-steel non-twisting ropes passed round two-fold blocks, the free ends being carried to a twelve-ton ground crab-engine fitted with two clutch-geared drums in the usual manner. Each pumping-engine consisted of a tandem compound pair of cylinders 21 in. and 36 in. by 60 in., set on to a wrought-steel built up bed-frame, and geared three to one, by means of steel helical gearing, to a second motion shaft fitted with a steel pumping disk arranged so as to permit of the stroke of the pumps being varied from 4 to 6 ft. to suit the volume of water in the pit bottom, the steam-pressure available being 160 lbs. per sq. in.

One pumping engine with two sets of 30 in. pumps was put down at the north shaft, two pumping-engines with four 30 in. sets at the south shaft, and one pumping-engine with two 30 in. sets at the east pit, all duplicated throughout.

The north shaft was begun on November 6, 1900, and was finished 20 ft. in diameter down to the Hutton Seam level, at a depth of 419 yards, on July 23, 1904, after passing through 155 yards of boulder clay, magnesian marl, and limestone, 48 ft. 10 in. of soft grey sand below the latter, and 248 yards of ordinary coal measure strata. During this period the maximum feeders of water pumped from this shaft with one pair of 30-in. pumps was 4,650 gallons per minute, and 1,500 to 2,000 gallons per minute whilst sinking through the soft grey sand below the limestone at a depth of 188 yards. To dam the feeders back into their natural channels, 106 yards of cast-iron tubbing $\frac{7}{8}$ in. to $1\frac{3}{8}$ in. in thickness was put in, and 313 yards of 14 in. walling in addition, to secure the shaft sides.

The south shaft was commenced on February 28, 1901, and was completed 20 ft. in diameter down to the level of the main coal seam, at a depth of 302 yards, on September 1, 1905, after passing through 158 yards of boulder clay, magnesian marl, and limestone, 39 ft. 2 in. of soft grey sand, and 131 yards of coal measures.

During this period feeders of water amounting to 6,310 gallons per minute were encountered and successfully tubbed back in the limestone, and 1,200 gallons per minute in the sand. One pair of 30 in. bucket pumps handed the feeders without difficulty, the duplicate pair being utilised in cases of emergency, and more particularly when passing through the sand. One hundred and twenty-one yards of cast-iron tubbing $\frac{7}{8}$ in. to $1\frac{3}{8}$ in. in thickness was fixed in position, and also 180 yards of 14 in. walling to secure the shaft sides.

The east shaft was commenced on September 3, 1900, and was completed, 17 ft. finished diameter, down to a depth of 406 yards on November 6, 1905, after passing through 152 yards of boulder clay, magnesian marl, and limestone, 61 ft. 9 in. of soft grey sand, and 234 yards of coal measures.

During this period the maximum feeders of water encountered and pumped by one pair of 30 in bucket pumps was 6,100 gallons per minute from the limestone, and 3,200 gallons per minute from the sand. One hundred and fifteen yards of cast-iron tubbing was placed in position to keep back the feeders of water, also 291 yards of 14 in. brick walling to secure the shaft sides. Owing to the soft character of the sand this shaft had to be piled, and the time actually occupied in sinking and safely securing the pit into the coal measures from a depth of $152\frac{1}{2}$ yards down to 178 yards was twenty-seven weeks.

The maximum feeders of water pumped simultaneously at any one period amounted to 9,230 gallons per minute, from the east and south shafts, from September 23 to November 26, 1903.

The actual volumes of water pumped were measured daily at 12 noon, by means of a large tank suitably arranged for the purpose at the outlet end of the delivery-drift.

The production of coal from this property is now averaging 1,000,000 tons per annum.

**Air Pumps and Condensers** (R. M. Ferguson, M.Sc., Proc. Manr. Soc. Engrs., Feb.). —It is of great importance to know what is the limiting vacuum obtainable under certain conditions. The term vacuum, as used by engineers, is a variable quantity dependent upon atmospheric conditions, and all figures should be reduced to a standard barometer of 30 in. mercury. It is much better to speak of absolute pressure in a condenser, for it will be independent of any direct atmospheric variation. A disadvantage is that this pressure cannot be measured directly, but must be arrived at by observing the pressure in the condenser below atmosphere and also the actual atmospheric pressure.

The absolute pressure in a condenser is composed of two independent factors, the steam or vapour pressure, and the air pressure. Considering these two quantities first in the case of a jet condenser with a wet air pump, the author arrives at a formula for estimating the absolute pressure in a condenser in terms of the injection water per lb. of steam, the initial temperature of this water and the bucket displacement.

$$p = p_a \frac{1{\cdot}8 + {\cdot}033\,L + {\cdot}02\,n}{62\,u - (n+1)} + \frac{22{\cdot}86}{n} + 0223\,t_o - 1{\cdot}29.$$

Where $u$ = bucket displacement in cubic feet, $n$ = lbs. of condensing water per lb. of steam entering condenser at temperature $t_o$ : $p_a$ = atmospheric pressure.

The author applies this to show that admitting too large a quantity of injection water decreases the vacuum obtained, lowers the temperature of the hot well, and decreases the efficiency of the plant. In the case of counter current jet condensers (including the barometric type) the expression given for determining the condenser pressure is:—

$$p = p_a \frac{1{\cdot}8 + {\cdot}003\,L + {\cdot}02\,n}{62\,u} + \frac{3{\cdot}9}{n} + {\cdot}019\,t_o - {\cdot}867.$$

It is shown that the vacuum obtained by this type of condenser is much higher than in a parallel current system using the same quantity of water and steam.

With regard to surface condensers it is not possible, from direct reasoning, to predict what vacuum can be obtained for a definite amount of steam and water due to the unknown action that occurs on the steam side. The rate of condensation depends on, amongst other things, the pressure of air in the steam space; air corresponding to the pressure of $\frac{3}{30}$ in. reducing the rate of condensation by 50 per cent.

From the equations which represent the several actions that take place in a condenser, assuming the steam to be at a constant temperature, Dr. Nicolson has deduced the following equation:—

$$\frac{4l}{d} = 120\left(5 + R\sqrt{u}\right)\log_e \frac{t_0 - T_1}{t_0 - T_2}$$

$l$ = length of tube. $d$ = diameter. R = ratio $\frac{\text{water.}}{\text{steam.}}$
$u$ = velocity of water. $t_0$ = temperature of steam.
$T_1$ and $T_2$ = initial and final temperatures of waters.

This equation does not enable one to determine what vacuum will be obtained in a given condenser; but it does indicate at least in what direction alteration should be made to increase the efficiency. Such increase may be obtained by increasing $l$, decreasing $d$, or increasing the speed of the circulating water. The results of experiments carried out by the author are given which bear on the above points.

**A Commercial Method of Manufacturing Hydrogen.**—A new method of generating hydrogen gas for commercial purposes such as the filling of balloons or for use in autegenous welding by the oxy-hydrogen flame, has been evolved by Prof. Adolf Frank of Charlottenburg. Water gas is liquefied in a "Linde" apparatus and as liquid carbon monoxide has a vaporisation point of − 190°, and liquid hydrogen − 253°, the separation is easy.

The energy required for liquefying the gas in this case is, according to calculation, so small that the whole energy can be obtained by burning the separated carbon monoxide in a gas engine, which gives an economically and technically interesting cyclic process.

According to *Electro Chemical and Metallurgical Industry* a small, but commercially complete plant has been equipped, with its own water-gas producer for generating 10 cubic metres of water gas per hour. Since the generation of 2,000 cubic metres of pure hydrogen is sufficient for filling three balloons for military purposes, only a single water-gas producer is required. The other apparatus require only small space and little attendance. Besides coke, a moderate supply of carbide is necessary. For a fortress which is being besieged and which cannot get hydrogen gas from outside, this method appears to have great advantages.

**Reversing Motor Drive for Planing Machines.**—In the course of an interesting paper on the planing machine read before the Coventry Engineering Society by Mr. T. R. Shaw, A.M.I.Mech.E., the author referred to the attempts that had been made to obtain a reversing motor drive. It appears that up to the present reversing motors have not been made which will give the quick returns and pick up the speed as satisfactorily as is essential for them to compete with the best belt driven machines. One of the most successful of these is a plate edge planer made by Messrs. Stirk of Halifax, in which the motor is a constant-speed machine coupled direct on to the driving screw. In order to bring the motor quickly to rest at the end of each stroke, an electric brake is attached, operating on the coupling. On this type of machine cutting takes place on both strokes, and the drive has proved very effective. In machines where there is some advantage in using a reversing motor, the mass of the moving parts is, comparatively speaking, light, so that the energy used in acceleration is small in comparison with that used in the actual cutting stroke. The points to be taken into consideration in these particular machines is the weight of the moving parts, the length of travel, and the number of strokes per minute. If the weight is small, the length of travel great, and the frequency low, then reversing motors can be used, and advantage taken of the absence of belts and other forms of gearing.

**The Longest Concrete Arch Bridge in the World.**—Construction is now far advanced on this bridge, that of 233 ft. clear span across Wissahickon Creek, Philadelphia.

From information given in the *Engineering Record* * we learn that the bridge is entirely of rubble or bastard concrete without reinforcement, and is 585 ft. long, 60 ft. wide, and carries an important thoroughfare through the park at a height of 150 ft. above the water. It has one 233-ft. main span with a 70-ft. rise, and five 53-ft. side spans. All spans are made with two separate twin ribs 18 ft. wide and 16 ft. apart in the clear. The radial depths of the main arch rib increase from 5½ ft. at the crown to 9½ ft. at the skewback, and each rib is made with 22 long voussoirs or sections and 17 keys. The ribs carry transverse vertical walls and piers supporting 20-ft. clear spandrel arches, which, in turn, carry longitudinal concrete walls on which the roadway platform rests.

* Vol. 57, No. 7.

The 53-ft. approach spans have monolithic arch rings with radial thickness varying from 27 in. at the crown to 42 in. at the skewback, and support longitudinal spandrel walls similar to those of the main arch. Horizontal transverse I-beams 20 in. deep and 6 ft. apart are carried on the tops of the spandrel walls and support the concrete jack arches forming the floor platform, which is uniform over the main and side arches. The total amount of concrete in the main span, exclusive of abutments, is about 6,500 cub. yards. In each rib it is about 1,700 yards, and each rib with its spandrel walls and spandrel piers contains about 2,400 cub. yards of concrete and imposed a maximum load of about 5,000 tons on its falsework.

**The Explosive Combustion of Hydrocarbons.**—In his recent lecture on this subject before the Royal Institution, Prof. Bone undertook and described some experiments on explosive mixtures under high initial pressure, results of which are of importance in view of their bearing on combustion as it occurs in the cylinders of internal combustion engines. The explosion apparatus used comprised a cylindrical steel bomb, measuring externally 12 in. by 4 in., and having a chamber 8 in. long and 1 in. in diameter. It had been previously tested by hydraulic pressure to 2,000 atmospheres. It was filled with an equimolecular mixture of ethane and oxygen to a corrected pressure of 15·8 atmospheres, and the mixture was fired. The pressure of the products was, after correction for dead space, 30·6 atmospheres, or rather less than double the initial pressure. An initial combination of hydrogen would have given a final pressure 2½ times that of the initial pressure.

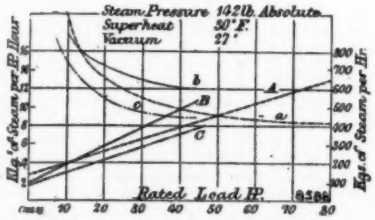
The foregoing figures are those obtained in the experiment carried out in the lecture theatre itself; but the results of a complete experiment made at a higher pressure are shown below. It should be observed that 7 per cent. of methane survives in the products, indicating the difficulty with which that hydrocarbon is oxidised at high temperatures. The products in the bomb were passed into ammoniacal solution of cuprous chloride; and it appeared therefrom that no acetylene had survived in them. It seemed likely that at higher pressures the methane would be decomposed to a greater extent, and the steam more acted upon by the carbon liberated; so that ultimately, if the pressure were high enough, the final products would be chiefly, if not wholly, carbon monoxide and hydrogen. Under such conditions there would be the appearance of a preferential combustion of carbon.

RESULTS OF EXPLOSION OF AN EQUIMOLECULAR MIXTURE OF ETHANE AND OXYGEN UNDER HIGH PRESSURES.

| | | |
|---|---|---|
| $p_1$ | | 25·2 atms. |
| $p_2$ | | 31·7 ,, |
| $p_2/p_1$ | | 2·05 |
| Percentage Composition of Gaseous Products. | $CO_2$ | 2·6 |
| | $CO$ | 37·2 |
| | $C_2H_2$, $C_2H_4$ | nil |
| | $CH_4$ | 7·0 |
| | $H_2$ | 52·2 |

| | C | H | O |
|---|---|---|---|
| Original mixture ... ... | 25·35 | 38·0 | 12·35 atms. |
| Gaseous products ... ... | 24·50 | 34·6 | 11·05 ,, |
| Difference ... ... ... | 0·85 | 3·4 | 1·5 |
| Difference per cent. ... | 3·4 | 9·0 | 12·0 |

**The "Belluzzo" Two-Speed Steam Turbine** (*Engineering*, February 28, 1908).—This turbine was designed by Sig. Mg. Belluzzo, of the Milan Polytechnic, with the idea of securing a not markedly less efficiency when running at half-power and half-speed than at full power and speed. Working under the latter conditions the turbine operates as a two-stage velocity compounded turbine, with three rows of moving buckets per nozzle. When working at half-speed a third wheel is brought into requisition in which each bucket is divided into two portions, one-half of which is utilised for reversing purposes when going astern and the other portion of the buckets when going half-speed ahead. Steam in this instance is supplied by a separate set of subsidiary nozzles at the bottom of the casing and passes in succession to the other two wheels—in an opposite direction to that when working at full speed—before reaching the condenser. When reversing the third wheel is fed with steam by a separate nozzle at the top of the casing. The results of the trials are shown in the accompanying figure, and indicate that the design is likely to become of importance in marine work.




Pressure, 242 lbs. abs.; Superheat, 30 deg. Vacuum, 27 in.

Curves *A* and *a* show respectively the total consumption and the consumption per b.h.p., running at 3,000 r.p.m. with the main nozzle in use. Curves *B* and *b* show results when running at 2,000 r.p.m. with steam throttled at the main nozzles, whilst curves *C* and *c* show the results obtained at 2,000 r.p.m. with the subsidiary nozzles. The *C*, *c* results will be seen

to compare favourably with those obtained at 3,000 r.p.m.

**Tests of an Exhaust Steam Turbine Plant** (H. M. Wait, Proc. Am. I.E.E.). —The first exhaust steam turbine plant in the U.S.A., used in connection with blooming mills, is installed at the Wisconsin Steel Company's mill, Chicago, and has been subjected to a series of tests. The primary engine is a 42 in. by 60 in. double-cylinder reversible rolling-mill engine, the exhaust steam from which passes to a receiver which takes out the shocks of the puffs of steam, thence to a steam accumulator, and from there to the turbine and condenser. The results of the tests show that the primary engine delivers to the regenerator an average of 52,400 lbs. of steam per hour and develops 1,010 i.h.p., or 54 lbs. per i.h.p. during the running period. This large consumption is due to the engine taking steam for practically the full stroke during the passes, and is running on light load for the rest of the time. The tests on the turbine showed that it took 33·6 lb. per electrical h.p. hour. This would make available at the switchboard 1,560 h.p. or a total of 2,370 h.p., after deducting the engine friction; that is, 22·1 lb. of steam per total h.p. at the shaft as against 38 with a reversible condensing engine of the best type. In other words, the condensing engine would take about 70 per cent. more steam per effective horse power than the combined high-pressure engine and turbine. This result is checked by the experience at the Poensgen Steel Works, Dusseldorf, in which various engines of the plant were connected to a central condensing system which effected a saving of 15 per cent. in the amount of steam used. Afterwards a "Rateau" steam regenerator plant was installed, and the exhaust steam put through the turbines. The saving now exceeds 40 per cent. as compared with the average of a 15 per cent. saving by running all their engines into the condensing system. The saving in this case is not as great as the example we have just cited, because the engines are not all reversible and are consequently more economical to start with. In general, it will be found to work out that the combination of a low-pressure turbine with a high-pressure engine is a more economical unit than a condensing engine alone; and it frequently figures out to a lower steam consumption than a high-pressure and low-pressure turbine or a high-pressure condensing turbine.

**A Producer Gas Motor Vehicle.**—The feasibility of utilising a producer gas plant for driving a motor vehicle has led, after much experimenting, to the introduction of a reliable plant. The owners of the patents, the Automobile Gas Producer Syndicate, 93, Hope Street, Glasgow, have communicated to us the results of some trials conducted with a car fitted with a producer plant and an ordinary petrol engine. The engine compression was increased, however, and a three-way cock was fitted between the inlet pipe and carburetter so that either producer gas or petrol could be used. The car alone weighs 4 tons 6 cwts., and with passengers and a full day's load of fuel, about 5 tons. The consumption on trial on a 35½ miles non-stop run through traffic is stated to have been 189 lbs. of fuel for 173 ton miles, or 1⅛ lbs. of anthracite peas per ton mile. Under similar conditions 4 galls. of "Shell" spirit were used in 17 miles, being 21¼ ton miles per gallon. The price paid for the spirit was 1*s.* 2*d.* per gall. and for the anthracite peas sifted and cleaned 20*s.* per ton.

At those rates we have: With petrol, ·67*d.* per ton mile; with producer gas, ·12*d.* per ton mile, or a saving of 82 per cent. over petrol, the other running expenses being equal for either form of power.

The producer gas results have been obtained under the very worst conditions. Instead of an engine with separate mechanically worked gas and air valves, the one used was an ordinary petrol engine, which has, of course, only about one-half the correct inlet area for the explosive mixture of gas and air. Owing to this method of using the gas there requires to be an opening in the gas pipe to allow the air and gas to mix before reaching the engine. Such an arrangement causes a two-fold loss on the one hand, due to the escape of gas at certain engine speeds, and on the other, to an incorrect mixture of gas and air.

It is a well established fact now that one b.h.p. per hour can be obtained from one pound of anthracite; a simple calculation shows that producer gas gives a theoretical saving of 90 per cent. over petrol, and the syndicate are sanguine that this figure will be approached for cars with a specially designed engine and chassis.

Another important plant which has been proved in the trials is that the exhaust is free from smell and is invisible.

Full drawings and details of the plant are at present not available, but we hope to be in a position to publish these later.

## Locomotive Feed Water Heater.

Although the practice of heating boiler feed water to or near boiler temperature is not a common one in this country, yet the method has several attendant advantages, and has been given practical attention on the L. & S. W. Railway and on the Egyptian State Railways.

A recent instance is provided by the Central of Georgia Railway, who have just fitted a locomotive with an interesting apparatus, utilising waste heat for feed heating purposes, the details of which are given in the accompanying illustrations. The component parts will be seen to consist of a duplex horizontal feed pump, two heater drums fixed under the running board

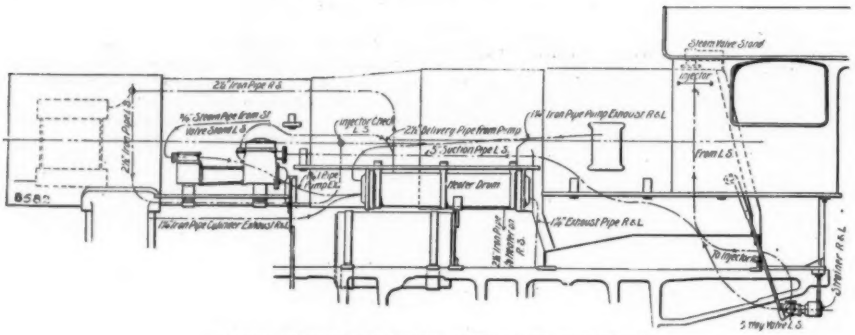
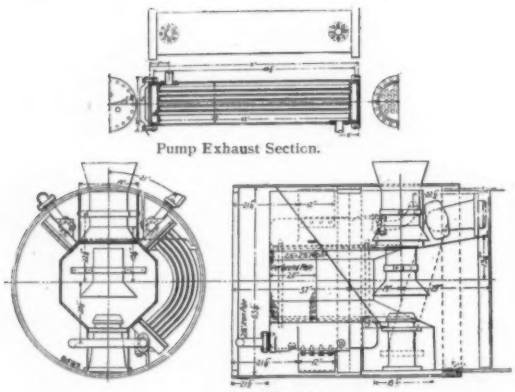



DIAGRAM SHOWING THE COURSE TAKEN BY THE FEED WATER.

(From the *Railway and Engineering Review.*)



Pump Exhaust Section.

Front End Section.

LOCOMOTIVE FEED WATER HEATER.

on either side of the engine, and a nest of tubes at the front end. A number of tubes are fitted in the drums through which is passed the exhaust steam from feed and air pumps, and a certain proportion of cylinder exhaust. The feed water is passed through the drums at a velocity of about 16 ft. per min. by means of the duplex pump, absorbing in its passage much of the heat from the steam passing within the tubes. The feed water next passes to the nest of tubes which constitutes the main heater at the front end, to be afterwards fed into the boiler through the usual check valve. It is expected that the temperature of the water when delivered to the boiler will reach over 300° F., but no figures are at present available to show this. Tests, however, are being carried out, and the results will be watched with interest.

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THE new 33 knot "Tribal" type destroyer *Tartar*, built by Messrs. John I. Thornycroft & Co., Ltd., which achieved a notable record by maintaining a speed of 35·363 knots throughout a six hours' trial, and 37·037 knots as the best single run in December last, recently carried out the official twenty-four hours fuel consumption trial.

Notwithstanding the severity of the test, and adverse climatic conditions, the trial was entirely successful and to the satisfaction of the Admiralty officials on board.

The stipulated speed of 13 knots while running economically was exceeded, the actual speed during the period being 13·105 knots, while the consumption of the Thornycroft boilers using oil fuel was within the limit provided for in the Admiralty contract.

Messrs. Thornycroft successfully launched recently another of the first-class turbine torpedo boats they are constructing for the British Navy, at their Southampton works. This vessel, No. 20, is 180 ft. long, and similar in general respects to the other vessels (originally called coastal destroyers) which have been launched from the same yard. The guaranteed speed is 26 knots, and the boilers will use oil fuel. This is the seventh boat of the same type launched by the Thornycroft Company, and there are two more now on the stocks.

*By ANDREW STEWART, A.M.I.E.E.*

## Electric Supply and the Factory Owner.

Some philosopher once said that a man never gave good advice until he was too old to show a bad example. It might be amended to imply that good advice is usually forthcoming when the opportunity to show a bad example is absent. This occurs to us as we read the reports of the discussion on Mr. John F. C. Snell's paper on the "Cost of Electrical Energy for Industrial Purposes," for we wonder what would be the opinion of many of these advocates of public power supply, if they owned a factory and were face to face with the problem of private plant versus public supply.

Our readers are familiar with most of the arguments for public supply, chief of which are that the capital which might be tied up in the generating plant is free to be employed in the ordinary business of the factory, and the owner is free from the cares of power generation—a business which is foreign to his vocation as a manufacturer—and purchases power just as he might purchase any other raw material.

The question has other aspects not always considered; for instance, it is not clear that the factory owner can purchase his power as cheaply as he can generate it. Wholesale generation is undoubtedly cheap, but wholesale distribution introduces a charge which is not inconsiderable; moreover, the management and similar charges per unit ($1\frac{1}{3}$ h.p. hours) are inevitably higher with a public, than with a private, plant. As an instance of this difference we might cite Mr. Yerbury's remark to the effect that Sheffield Corporation supplied current for power at prices down to ·6*d.* per unit, while the works costs were ·39 pence; referring apparently to power supplied from the tramways power station, from which a direct current is supplied for industrial purposes. The lowest possible charge for power on, presumably, a high load factor, is therefore about 55 per cent. higher than the bare cost of production.

It probably represents the irreducible minimum, inasmuch as the system is not burdened with the heavy distribution charges which a power supply from an extensive network of distributing mains must bear, as the supply is taken from certain points on the network of tramway feeders, which are earning money over a large part of the day, and the private power supply may or may not bear its due share of the capital and maintenance charges thereon.

The private plant, if of reasonable size and well cared for, should do quite as well as the power supply authority. It appears from Mr. Hooghwinkel's paper read recently to the Sheffield Society of Engineers that the Powell-Duffryn Co. in South Wales produce their electric power at ·3 to ·4 pence per unit, including capital and management charges, a figure that would barely pay the distribution costs of some companies.

A works can easily put in a private generating plant at £16 to £20 per k.w., and what public supply authority can do better?—while the running and standing charges will, if they figure out at that just mentioned, defy the competition of a public supply.

There remains, however, another feature of public electric supply not hitherto brought prominently before the public notice, viz., the entire dependence of the works on outside supply. A works is, of course, dependent upon external sources for fuel and raw material, but stocks of either can be accumulated, and there is generally one or two days' stock at least; but what has recently impressed itself on the works owner's mind is, that by taking power from the outside, he hands the mainspring of his works over to an outsider who

may be wholly out of sympathy with him, or his difficulties.

Messrs. Laing's shipyard at Sunderland is an example. In this case the local authority, finding they could not get their bills for electric current paid, cut off the supply, shutting down the works almost without warning.

It is not our intention to enter into the legal aspect of the matter; there is no doubt from the terms of supply, that any supply authority may cease to serve a consumer if his bills remain unpaid, but there are many cases where a factory owner does get into a financial corner, and his only hope is long credit. Arbitrary action by the supply authority might, by throwing the works idle, destroy any chance there might be of getting out of the difficulty, and no works owner is likely to accept that risk without seriously considering the alternatives.

One has only to think of the large number of manufacturing undertakings, large and small, which at one time or another have had to depend on the good will of their creditors to help them out of a difficulty, to realise that if the public supply authority holds the undertaking, metaphorically speaking, in the hollow of its hand, it would be an intolerable menace to the owner or owners, and one likely to lead to an increase in the number of private plants at the earliest opportunity.

The action of the Sunderland Corporation has done a good deal to shake the faith of works owners in public supply, and it has inflicted no small amount of "moral and intellectual damage," to use the historic phrase of the late head of a defunct republic, on its own and other undertakings. Moreover, it suggests possibilities: a works may have a serious strike in progress; if it is wrong to supply labour to a works under such conditions, a democratic town council might decide that it is equally bad to supply power if the works are to be run by blackleg labour; indeed it might be difficult for a local authority, with democratic sympathies, to resist the pressure that their supporters, who may be trades unionists, might bring to bear on them. We have known carters refuse to deliver fuel to a works where there was a strike; is it much more unreasonable to suppose that a democratic town council would refuse to supply electricity? There are many different ways of getting fuel, but only one way of getting electric power, if you buy it from the supply authority.

Public electric supply may ultimately become the only source of power for small industries, and the man with limited capital starting in a small way; but we doubt if it is the natural or economic function of a supply authority to run mills and factories, though many will be so operated.

It is interesting to note, in this connection, that during 1907 the Glasgow Corporation increased its motor load from 11,950 h.p. to 19,800 h.p., a 65 per cent. increase, and Coventry from 2,346 h.p. to 3,880, almost exactly the same percentage increase. These stations are located in what are perhaps the most rapidly-developing industrial districts in the world. Glasgow and district in particular has, during the last five years, shown a development absolutely unparalleled by any industrial community, and the progress of Glasgow Corporation's power load is but an imperfect index of this, as there are other supply authorities, for instance the Clyde Valley Power Co., who manage to double their output month after month.

## New York Central Railway Electrification.

We have already dealt with the principal engineering features of this scheme, but a paper read to the American Society of Civil Engineers, by Mr. William J. Wilgus, supplies some data of value to engineers on this side of the Atlantic, and of a nature not hitherto available.

Mr. Wilgus does not brim over with enthusiasm for electrification, hence he is more level-headed on controversial questions than enthusiastic electrical engineers who in a decade or so have swept steam, horse, cable, and compressed air systems of traction and transmission from our tramways, workshops, and mines, and who would relegate the steam locomotive to the scrap heap to-morrow, were it in their power to do so.

For instance, Mr. Wilgus rightly says that the steam locomotive, during a lifetime of eighty years, has been developed into a wonderfully able, efficient, and powerful machine, deeply rooted in the affections of the railway world, and that it was not primarily the hope of economy which led the companies interested in the New York Central and Hudson River lines to electrify, but the demand of the public and the civic authorities, for some mitigation of the atmospheric conditions in the tunnels leading to the terminus, though the congestion of the traffic was a contributing factor.

Among the reasons which the author of the paper gives for not using alternating current locomotives, is that the alternating

current locomotive when built to operate on both direct and alternating current circuits is a much less efficient machine than if built for direct current alone, the greater consumption being set down at 15 to 25 per cent., and less ton miles per locomotive, because of the lighter weight of the direct current apparatus.

We do not know where the experiments giving such differences in current consumption were made, but are inclined to think that the author's figures are more apparent than real, being due no doubt to the magnetising or wattless current of the alternating current locomotive, which does not represent real power; certainly the difference in efficiency, if it exists at all, is a mere fraction of that indicated, and is more than offset by the saving in capital and operating expenses due to the elimination of sub-stations containing moving machinery which are essential with direct current, and unnecessary with alternating current.

In passing, the author of the paper pointed out that by using steam turbines, the power station space was 110 cubic ft. at Yonkers Station, and 115 cubic ft. at Port Morris, against 170 to 255 cubic ft. per k.w. capacity in the case of the best planned stations using reciprocating engines.

It is calculated that the peak-load, which may last for 4 mins., may reach 32,000 h.p., when 38 trains aggregating 9,800 tons are in motion. Both power stations will have an output of about 121,000,000 units per annum (about 163,000,000 h.p. hours). Ninety per cent. of this will be utilised for propelling trains, the balance for station lighting, and similar work.

There are 35 electric locomotives each weighing 94½ tons and capable of developing 2,200 h.p., with a maximum of 3,300 for short periods. In addition there are 125 motor cars on suburban trains, and the aggregate h.p. is 127,000. These figures will serve to give the reader some idea of the magnitude of the traffic handled at the New York Central terminus, for the electrification question is purely a terminal problem at present, the electrically operated lines extending 7 miles out on one section, and 13 miles out on another. Through traffic is handled by changing from steam to electric locomotives at the beginning of the electrified section. The reduction in train weights are given by the author as—

| Steam. | Tons. | Electric. | Tons |
|---|---|---|---|
| Pacific type locomotive | 171 | Electric locomotive | 94½ |
| 8 Pullman cars ... ... | 400 | 8 Pullman cars ... | 400 |
| Total weight ... ... | 571 | Total weight ... | 494½ |

This shows a saving of 76½ tons or 13 per cent.

No figures are given as to the difference between steam and electric haulage on suburban trains, but a suburban train hauled by an electric locomotive weighs 294½ tons, while with multiple unit operation they weigh only 238½ tons, 19 per cent. less.

The time lost changing from steam to electric locomotives, at the end of the electrified portion of the line, is 4½ mins. for through trains, and 2½ to 3 mins. with suburban trains.

The author gives much valuable information in tabular form, figures which indicate generally that there are savings on almost all items when electric traction is introduced. These are of the order of 19 per cent. in locomotive repairs and fixed charges, 18 per cent. saving in dead time for repairs and inspection, 25 per cent. greater daily ton mileage, 12 per cent. net saving in cost of hauling trains.

The period under which the electric locomotive has been under observation is about one year in actual service, but there seems no reason to anticipate any considerable change in these costs after the expiry of a longer period.

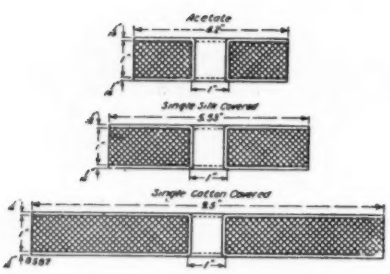
A useful item and one which steam locomotive engineers will find helpful, is the figure for electrical energy to do the work of one pound of coal. It appears that 79 watt hours do the work of a pound of coal on shunting work, and 43 watt hours do the same under normal running conditions such as handling heavy main line trains.

Incidentally, the electrification has increased the capacity of the terminus by about one third, thus postponing a still greater capital outlay for early enlargement which would have become imperative if steam had been retained.

There is still much data which will become available when the electrification scheme has been longer in operation, and when experience has been gained in hauling trains over the longer distances which will be opened up to the electric locomotive when the extensions now contemplated are completed; meanwhile it is gratifying to note that, so far, the results have proved that electricity is of great value for terminal service, though as the traffic becomes less dense, it is doubtful if the results now achieved could be maintained.

## Cellulose Acetate Covered Wire.

Our readers are no doubt aware that damp is the most insidious enemy that




SPOOLS WOUND WITH CELLULOSE ACETATE COVERED WIRE.

electric machinery and apparatus has to face. The usual covering, silk, cotton, or tape, is so hygroscopic that, even when impregnated with water-resisting varnish, it frequently fails to maintain its insulating properties in damp situations. The problem may appear simple to engineers not actually face to face with the difficulty, but efforts to find an insulating covering for electric wires, possessing all the essential mechanical and electrical properties, yet avoiding the apparently inherent defect already alluded to, have proved almost fruitless.

Some years ago the writer saw in Germany a number of motor coils wound with enamelled wire which were so invulnerable, so far as their chief enemy, damp, was concerned, that they could be completely immersed in water without apparent damage. The process never became commercially successful probably because the covering did not possess the same flexibility, or the same coefficient of expansion, as the wire itself.

We learn, from the *General Electric Review* (U.S.A.), that wires covered with Cellulose Acetate are being used chiefly for fine wires, and the results appear to be satisfactory; the covering is thinner than silk, which is the thinnest material possessing high disruptive strength that has so far been used for the purpose.

The three diagrams show coils wound to give the same number of turns in each case, and the superiority of the new covering is obvious.

The wire is coated with the film by automatic machinery, and should prove as cheap as cotton covered wire.

## Notes concerning Non-Parallel Axle Trucks and Bi-Rail Traction.*

In quite a readable monograph, Mr. J. Sutherland Warner, A.M.I.Mech.E., discusses problems of oscillation and rail and wheel wear on railway and tube carriages and tramcars. The keynote to the book is the "Conformity" line which is defined as "the most perfect path a vehicle running in a given track could follow." How far from the perfect path the ordinary tram or train does stray will be appreciated by any one who watches the disappearing rear of an express train or stands between the tramlines at the foot of a decline and watches the oscillation of a tram coming towards him at any speed. But the greatest authority — and the most eloquent — on this branch of engineering science is the "Strap-hanger," and we believe that the aim and object of this little book will meet with his most hearty approval.

Mr. Warner's solution of the problem is the use of non-parallel axle trucks in place of the usual truck frames in which pairs of axles are held rigidly parallel to each other.

The arrangement of the truck is simple, and consists of the ordinary sub-truck or radial frame with a king pin. From the ends of the axle boxes links are suspended by pins in such a manner that the links can conform to the radial movements of the sub-truck. The bottom ends of the links are coupled to a spring carrier, the lower pins being at the same angle as those above. The bottom of the main frame is slotted to allow the links to swing without restriction like the bolster suspension links on a railway carriage bogie.

The steering of the vehicle by the rails is thus through wheels, sub-truck to the main truck and carriage body, the direction of the latter being changed only after that of the rolling plane of the wheels and when the latter have rolled in the new direction sufficiently long to give an inclination to the links. Mr. Warner claims that his non-parallel trucks allow the carriage to maintain a steady course along the centre of the track, in other words to follow the conformity line, which the public demonstration he gave a few weeks ago fully maintained.

* Published by Phipps & Connor, Tothill Street, S.W

# Iron, Steel and the Foundry.

*Conducted by PERCY LONGMUIR.*

## FOUNDRY PRACTICE.

**The Production of Malleable Castings.**—In the current issue of the *Foundry*, Dr. Moldeuke commences a series of articles which, coming from such an authority, promise to be of exceptional interest. The opening article takes the form of a general review, and attention is drawn to the extremely slow development of knowledge underlying the principles of the manufacture of malleable castings. In the author's words:—"We may safely say that beyond the fact that white castings, made of certain brands of iron mixed and melted in certain ways and then annealed would produce serviceable malleable castings, nothing specific which would serve as a guide in daily work was known prior to 1890."

As the processes involved are not difficult to conduct even by rule of thumb methods a large industry has developed in the United States, and the production of malleable castings for 1907 has been estimated at over 950,000 tons. The output of European foundries has been placed at 50,000 tons for the same period, and of this Britain and Germany are credited with the greater portion. Reaumur's work of 1772 represents the first record of the production of malleable castings. Technical literature of the following century and a half throws no further light on the subject. Seth Boyden, of Newark, was the pioneer manufacturer of malleable castings in the United States, and his recorded experiments stand as a monument to his memory. These experiments were conducted at a time when the scientific study of industrial problems was not encouraged. Even though Boyden failed to solve the underlying principles involved in the production of malleable castings, he accomplished more than others before him. The fact that the process did not advance was largely due to the regularity of the pig iron and to the ability of the melter to estimate annealing temperatures by eye. Reaumur and Boyden left notes explaining their methods, but others did not do so. Even ten years ago the majority of the older malleable works were producing castings by archaic methods, with possibly some improvements in the furnaces and ovens to increase their capacity. The dawn of progress followed the introduction of coke iron. Charcoal iron had previously been regarded as indispensable, but in spite of the troubles met coke iron gradually gained ascendancy. Another forward movement was found in addition of scrap to the mixture, and concurrently with this, annealed scrap was also used. The use of the latter greatly increased the strength of the castings, and this introduction of malleable scrap into the charge marks one change from ancient to modern practice. Another development is found in the chemical laboratory which has contributed largely to the advance of the industry. Further advancement is dependent upon the solution of problems dealing with the constitution of malleable cast iron. For example, it is not known why cupola malleable requires a higher annealing temperature than air furnace or open hearth metal. The underlying principles of the oxidation of the bath, a frequent source of defective iron, is practically unknown to those engaged in the industry. Heats are frequently made that will not pour or anneal properly, but the causes are still being sought. To produce castings from successive heats so that with the same composition they will have the same physical properties, is a problem partially solved for steel, but not yet approached for malleable cast iron.

**Melting Iron in the Foundry Cupola.**—Professor H. McCormack gives, in *Electro-chemical and Metallurgical Industry*, some data on cupola practice derived from observations made on a cupola working in the Armour Institute of Technology. The cupola is of the "Whiting" type, and melting was conducted in the

usual manner. Much detailed information is given, but perhaps special interest is attached to the temperatures of the escaping gases. Blowing commenced at 2·56, and the temperature of the gases taken then and at subsequent intervals is as follows:—

| | | | | | |
|---|---|---|---|---|---|
| Time ... ... | 2 56 | 2 59 | 3 0 | 3 1 | 3 2 |
| Temperature °C... | 105° | 250° | 282° | 372° | 465° |
| Time ... ... | 3 3 | 3 4 | 3 5 | 3 6 | 3 10 |
| Temperature °C... | 480° | 545° | 665° | 760° | 851° |
| Time ... ... | 3 23 | 3 27 | 3 30 | 3 35 | |
| Temperature °C... | 945° | 1090° | 1260° | 1275° | |

Bottom dropped 3·35.

Analyses of the iron and coke, details of charging, and full data as to blast are given. From these a series of calculations are worked in full detail, which are perhaps a little too intricate to note in full. However, these calculations lead to the following summary, and the figures given are of very great interest.

| | | Per cent. |
|---|---|---|
| Calories to heat air ... ... ... | 295,576·8 | 57·3 |
| Calories to heat and melt iron ... | 123,922·1 | 24·1 |
| Calories to form and heat slag ... | 27,130·9 | 5·3 |
| Calories to heat cupola bricks ... | 28,440·0 | 5·5 |
| Calories for radiation (by difference) | 399.90·5 | 7·8 |
| Total ... ... ... | 515,060·3 | 100·0 |

The melting loss in carbon and silicon of the pig iron is given, and the amount of heat developed by the oxidation of these elements worked out. The summary of calories developed is as follows:—

| | |
|---|---|
| From coke .. ... ... ... .. ... | 466.682·0 |
| From the carbon of iron ... ... .. ... | 41.927·1 |
| From the silicon of iron ... ... ... ... | 6.451·2 |
| Total ... ... ... ... | 515.060·3 |

The gases escaped from the cupola at an excessively high temperature for the greater part of the time, being above 1,000° C. This could be lowered if more metal had to be melted, so that the escaping gases could be utilised in heating the charge, and shows that there is fuel economy in melting over a long period in a small cupola, rather than for a short time in a large one, as the principal fuel loss is in the heat carried away by the escaping gases.

**The Application of Science to Foundry Work.**—In a paper read before the Royal Society of Arts, Mr. Buchanan reviews progressive tendencies in foundry work of to-day, and shows that where scientific methods have been adopted good returns have followed. Scientific iron mixing is of recent origin, but its value is becoming more and more recognised by progressive foundrymen. Unfortunately many in charge of foundries have not had the requisite training in order to enable them to apply chemical and metallurgical principles. Where special qualities are required, such as strength, hardness or softness, they have to depend on brands of iron which by the progress of time have obtained a reputation for the particular quality desired. They are not aware that the qualities of an iron depend upon its chemical composition, and that no make of pig iron is always of the same quality. Instances of variation in composition are quoted, and the remedy shown to lie in buying to analysis, using that which scientific experience has shown to be desirable, and rejecting that which is unsuitable.

**Tensile Testing of Cast Iron.**—In a paper read before the Sheffield branch of the British Foundrymen's Association, Mr. F. J. Cook discussed in the first place the need for an intelligent specification when dealing with the tensile requirements of cast iron. The average specification reads, "Test pieces are to be taken from such castings as may be considered necessary by the inspector, and the minimum tensile strength is to be 9 tons per square inch on a length of not less than two inches."

As a result the general practice is to cast one size bar of 1¼ to 1½ in. diameter on all important castings, irrespective of the size and weight of castings the bar has to represent. It is generally known that the rate of cooling from fluidity determines in a large measure the properties of a cast iron. The rate of cooling is determined by the size of a casting, hence the rate of cooling in, say a torpedo boat cylinder, is vastly different from that of a 20 or 30 ton casting such as a large marine cylinder or fly-wheel. Yet under existing conditions the properties of either light or heavy castings are judged by a bar of the same size.

This influence of size is illustrated in another manner by the following experiments:—

| Diameter of bars as cast | ⅞ in. | 1⅛ in. | 1 in. | 1½ in. | 3 in. |
|---|---|---|---|---|---|
| | Tons per sq. in. | | | | |
| Tensile tests of first series | 9·26 | 10·72 | 11·6 | 12·61 | 8·35 |
| Tensile tests of second series | 13·2 | 12·6 | 11·9 | 11·1 | 7·0 |

The first series were cast from iron of average strength for castings of medium size, and it will be noted that the results are low for small size castings; the strength increases up to 1½ in. diameter, and then falls off. The second series represent ordinary No. 3 soft foundry iron, and it will be noted that whilst small castings are strong, the properties decrease with increasing size. The features thus shown are of very considerable interest to engineers, and they illustrate a fact familiar to all iron-founders. In considering the advantages

derived from chilling as an aid to produce a close grain, and not from the point of a hardened surface, Mr. Cook reports the following tests :—

| Analyses. | | | | | | Thickness of chill. | Max. stress. Tons per sq. in. | Gain per cent. |
|---|---|---|---|---|---|---|---|---|
| Combined carbon. | Graphite. | Silicon. | Manganese. | Sulphur. | Phosphorus. | | | |
| 0·234 | 2·804 | 1·96 | 0·50 | 0·11 | 1·10 | in.<br>0<br>$\frac{1}{8}$<br>$\frac{1}{4}$<br>$\frac{3}{8}$ | 11·6<br>15·15<br>15·6<br>White iron | —<br>30·6<br>34·4<br>— |
| Trace | 3·57 | 3·50 | 0·28 | 0·01 | 1·50 | 0<br>$\frac{1}{8}$<br>$\frac{1}{4}$<br>$\frac{3}{8}$ | 8·1<br>11·9<br>12·3<br>15·2 | —<br>46·9<br>51·8<br>87·6 |

The thickness of chill relates to the chill used in the mould, and not to any chilling effect on the casting. Except in one case the effect is purely a closening of grain, and the tensile results show the beneficial influence of the fine crystallisation thus induced. Finally the author gave a record of 100 consecutive tests of castings produced under normal foundry conditions over a period of several months.

SUMMARY OF 100 CONSECUTIVE TENSILE TESTS.

| | | | | | | |
|---|---|---|---|---|---|---|
| Number of bars broken below | | | 11 | tons per sq. in. | = | 0 |
| " | " | " | from 11 to 12 | " | = | 6 |
| " | " | " | " 12 to 13 | " | = | 13 |
| " | " | " | " 13 to 14 | " | = | 21 |
| " | " | " | " 14 to 15 | " | = | 30 |
| " | " | " | " 15 to 16 | " | = | 16 |
| " | " | " | " 16 to 17 | " | = | 10 |
| " | " | " | above 17 | " | = | 4 |

## STEEL : ITS PRODUCTION AND PROPERTIES.

**The Workshop Treatment of Steel.**—Writing in the Engineering Supplement of the *Times*, Mr. W. Rosenhain discusses the treatment to which steel is subjected in working up into shape. Whilst it is desirable that steel should be capable of withstanding such work without injury it is also equally desirable that the workshop manipulations should be so regulated as to inflict the minimum amount of injury upon the material. In practice the majority of manipulations are regulated by questions of economy and producing efficiency rather than by careful consideration of the peculiarities and requirements of the materials employed. In the case of steel there is, perhaps, some justification for this course since the metal is known to be ductile. Further, as mild steel will undergo severe deformation without breaking, it is not unreasonable to argue that the material should withstand the milder treatment of shops without injury. Unfortunately experience has shown that this argument is not always sound. In these cases engineers have a tendency to lay the blame on the steel, and to ascribe the failure to some mysterious fault in the metal. Whilst the possibility of faulty metal cannot be entirely precluded there is none the less reason to believe that enquiry into the shop treatment of the material would in many cases reveal the true causes of failure. The writer then examines some of the more familiar shop methods with a view to studying their effect in injuring the material treated. No really definite conclusions are reached, but a timely warning is given in the following :—"At the present time engineers are still too ready to lay the blame for any and every failure upon the material; it is quite true that there are still many things to be discovered as to the mechanical properties of steel, but in every case it is necessary to look for known causes rather than fly to unknown and mysterious ones. When the methods of engineers are above reproach they will be in a better position to put the blame for failures on the steel makers."

**Use of the Electric Furnace in making Alloy Steels.**—In the correspondence columns of *Electro-chemical and Metallurgical Industry*, Mr. R. H. Wolff states that the Héroult furnace is being largely used for the production of special alloy steels. The adaptability of the furnace for this purpose is said to lie in the absence of an oxidising atmosphere. Steel makers have found a considerable loss of ferro alloys in oxidising furnaces due to the oxidation of the added element, and the resulting oxides form solid particles remaining more or less distributed through the steel. In the electric furnace of Héroult the steel bath is protected from the atmosphere so that no reoxidation is possible.

Further, there is a continuous circulation in the bath, and there being no danger from oxidation or loss the liquid steel may remain in the furnace at any desired temperature for any length of time. The uniform distribution of any addition either in the form of ferro or otherwise is thus readily obtained, and a thoroughly homogeneous product results.

**The Theory of High Speed Tool Steel.**—In the *Iron Age*, Mr. Geo. Auchy reiterates much of the work done in this direction by Osmond, Böhler and Le Chatelier. As nothing new or original is presented, the matter calls for little comment; however, we cannot resist quoting in full one luminous paragraph specially written for the *practical* man.

*Points for the Practical Man to Consider.*—"But it is not necessary for the practical man to consider whether the theory of Osmond or the theory of Arnold be true. All that is necessary to understand, at least in this connection, is that steel may exist in three conditions according to temperature:—

"(1) Alpha, or at first and for the most part pearlitic (soft), and at the end martensitic (very hard); (2) beta, or martensitic or hardenitic (very hard); (3) gamma, or austenitic (medium hard). The transformation points of these conditions are in unsaturated or hypoeutectoid steels (steels under 0·89 per cent. carbon) at these temperatures; from pearlitic (soft) to martensitic or hardenitic (very hard) at 710° to 730° C. ($Ac_1$), from alpha iron to beta iron at 730° to 750° C ($Ac_2$), the steel in this beta range being still martensitic or very hard; from beta iron to gamma iron and from martensitic (very hard) steel to austenitic (medium hard and tough) steel at 810° to 830° C. ($Ac_3$). In steels over 0·89 per cent. carbon (supersaturated or hypereutectoid steels) these three transformation points $Ac_1$ $Ac_2$ and $Ac_3$ merge into each other at 710° to 730° C."

## Midland Railway West Line Extension and New Water Troughs.

Some extensive engineering works are now in progress on the Midland Railway between Burton and Birmingham. The new section of permanent way from Kingsbury to Water Orton is well advanced. This line, which is 3 miles long, will be an important addition to the resources of the Midland Company in the west district. Not only will it shorten the distance from the north to Birmingham and beyond by 2 miles, but it will, says the *Railway News*, also allow through trains to avoid the abrupt curve at Whitacre Junction, where all drivers are called upon to reduce speed to about 10 miles per hour.

For the present only two lines of rail will be laid, but sufficient land is fenced throughout for quadruple track, and all over-bridges are being built for four sets of rails to pass under them. On the west side of the Tame the ground rises, and a cutting about 6 furlongs in length is being driven through it. The western slope of the ridge dips steeply, and another embankment will carry the track thence to Water Orton. Although rapid progress has been made with this line, which was commenced in April, 1907, there is a great deal yet to be done, and it will probably be at least twelve months hence before the track is ready for traffic.

Another important work in the west district is the installation of pick-up water troughs on the permanent way between Haselour and Tamworth. For some years the Midland Company have had troughs between the rails at Loughborough, Melton Mowbray, and Oakley, near Bedford. Lately they were put down at Hawes Junction in the far north, and now it is the turn of Tamworth. Persons who see only the finished troughs would have little idea of the amount of preliminary work required before the simple-looking galvanised steel tanks can be fixed on the sleepers. For about half a mile the track has to be taken up and relaid at a level a foot lower. The ordinary ballast is taken out and heavy lumps of furnace slag substituted, so that the water which is flung out of the troughs in large quantities by the engine scoops will not wash the road away. At the side of the line wide drains have to be laid, and connected at intervals by cross culverts. All this has to be done while traffic is carried on, and it occupies large gangs of men for months. The up line at Tamworth has just been lowered, and the slag is now being put on. Whilst this work is in progress all trains are slowed down to a walking pace, and in consequence passengers have a good opportunity to see what is being done. It is expected that the troughs will be ready for the summer express service.

# Machinery, Appliances and Processes.

The Editor invites advance particulars, drawings, blue prints, photographs, and any data that will enable him to publish an adequate description in these columns of any new work, machinery, or installation, possessing special features of interest. The cost of publication and engraving is borne by us, and no compensation is expected. In the endeavour to produce a really high-class and technically valuable machinery section the Editor seeks the co-operation of engineers and manufacturers.

## Horizontal Pumping Engines for Kidderminster.

By the courtesy of the makers, Messrs. Andrew Barclay & Co., Ltd., Kilmarnock, we are able to give some leading particulars and detailed illustrations of a fine horizontal compound, surface-condensing pumping engine, recently supplied for the Kidderminster Town Council. The pumps are constructed to deliver 1,500 galls. of water per minute at a speed of about 15 r.p.m. against a head of 240 ft., including friction, and we understand that will be the normal quantity. They are, however, able to deliver 2,000 galls. per min. in an emergency with a speed of about 20 r.p.m. The engine cylinders are 26 in. and 44 in. diameter respectively, with a stroke of 4 ft., while the pumps, which are of the vertical

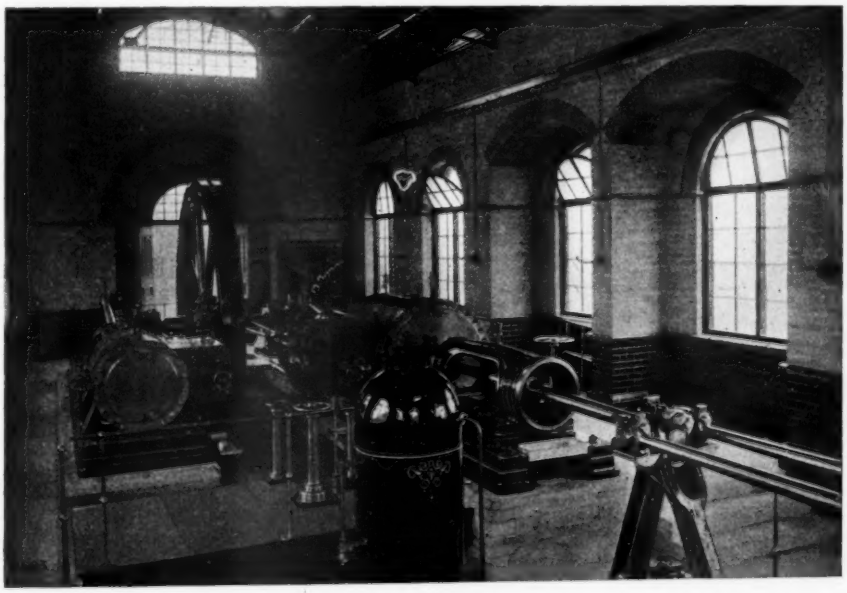


FIG. 1.—HORIZONTAL PUMPING ENGINE FOR THE KIDDERMINSTER TOWN COUNCIL.

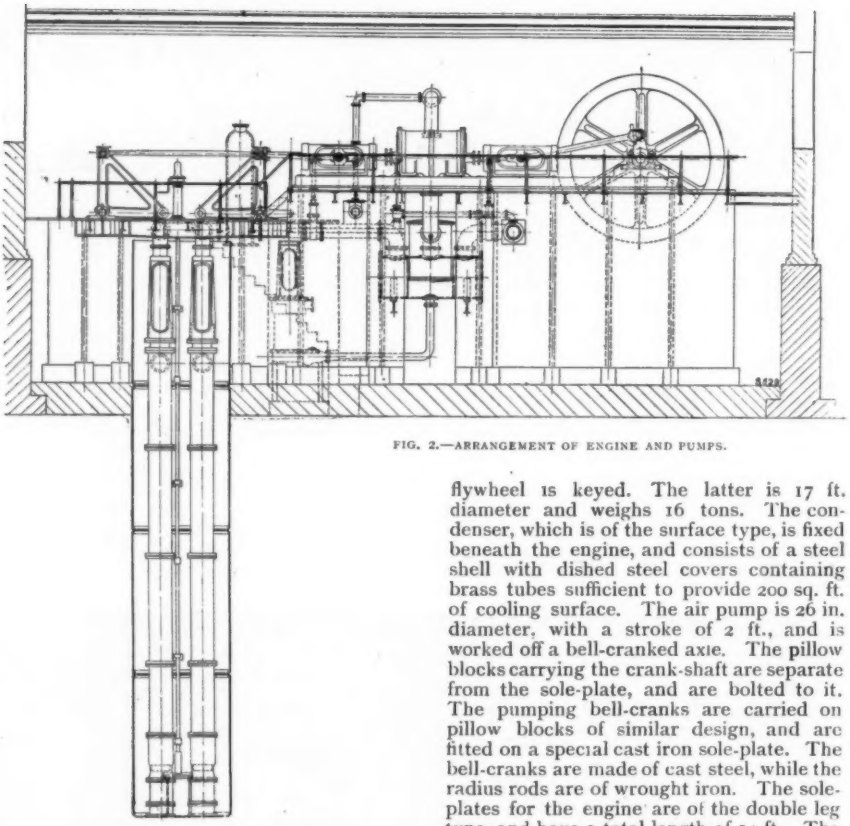


FIG. 2.—ARRANGEMENT OF ENGINE AND PUMPS.

bucket and plunger type, with buckets of 20 in. and plungers 14¼ in. diameter, are driven, as will be seen from Fig. 2, through bell-cranks. The low-pressure cylinder differs from the high-pressure cylinder in that it is provided with a cast-iron liner and steam jacket; both cylinders, however, have slide valves provided with "Meyer" expansion gear, adjustable by hand while the engine is running. The pistons are fitted with Lockwood & Carlisle patent packing rings, and Lancaster & Tonge's metallic packing is used for the piston rods and valve spindles. The cross-heads are of cast-steel, and the slides of cast-iron. The connecting rods, of best forged iron, are 10 ft. long, and the cranks are of forged steel. The shaft is 10 ft. over all, and has a journal at each end 9 in. diameter, increased to 12 in. on the boss to which the flywheel is keyed. The latter is 17 ft. diameter and weighs 16 tons. The condenser, which is of the surface type, is fixed beneath the engine, and consists of a steel shell with dished steel covers containing brass tubes sufficient to provide 200 sq. ft. of cooling surface. The air pump is 26 in. diameter, with a stroke of 2 ft., and is worked off a bell-cranked axle. The pillow blocks carrying the crank-shaft are separate from the sole-plate, and are bolted to it. The pumping bell-cranks are carried on pillow blocks of similar design, and are fitted on a special cast iron sole-plate. The bell-cranks are made of cast steel, while the radius rods are of wrought iron. The sole-plates for the engine are of the double leg type, and have a total length of 54 ft. The cylinders are lagged with asbestos, which is covered with planished-steel sheeting, and polished hand-railing surrounds the engine.

The working barrels of the pumps are fitted with gun-metal liners, forced into position by hydraulic pressure, and afterwards bored out. The suction valves, buckets, and bucket-valves are also made of gun-metal.

The plunger is made of cast-iron, and is turned all over. It is connected at the bottom end to the bucket by means of a wrought-iron rod 3½ in. in diameter, with a tapered socket, and cotters at the top and bottom. The top end of the plunger is guided by a cast-steel crosshead working in a bored guide bolted to the pump-cover. The connections between the cross-heads and the bell-cranks are forged wrought-iron rods. The rising main pipes are 12 in. in

diameter, and are each fitted with a 12 in. retaining valve. An air vessel is 2 ft. in diameter and 10 ft. high, and is provided with glass gauges for observing the quantity of air in the vessel.

The working pressure of the engines is 120 lbs. per sq. in. We may add that the consulting engineers were Messrs. Wilcox & Raikes, Birmingham.

## The "Proell" Steam Calculator.

The use of graphical charts as a means of calculation is growing more and more in popularity. One of the latest applications is in connection with certain steam calculations for turbine and reciprocating engines, some of which are thereby simplified, the utility of other results obtainable being not so apparent. The calculator is by Dr. Proell, and consists of three charts and an explanatory booklet. The co-ordinates for each combination of properties have been so chosen that each curve is reduced to a straight line. On the same plate there are eighteen linear scales which are so arranged and divided that almost all calculations upon the inter-related properties of steam may be performed by merely laying a straight-edge across the scales through two given points, and reading off the third corresponding value. Of the three plates one is divided in terms of the metric system of units; the second is of special interest to electrical engineers, who, accustomed to deal with energy in terms of kilowatt-hours, may appreciate the advantage of a calculating scale in which the unit of "total heat," or "total energy," is the kilowatt-hour per ton of steam; the third is based on B. T. Units. Examples of the method of use are given, such as: given the temperature $T$, pressure $P$, determine the total heat $I$, corresponding to the given temperature and pressure; given dry saturated steam of pressure $P$, which is to expand adiabatically, in a diverging nozzle, to atmospheric pressure, required the outlet section of the nozzle per unit weight of steam per second, and the sections corresponding to the various intermediate stages of the expansion. The calculator is published and sold by Messrs. John J. Griffin & Co., Ltd., Kingsway, W.C.

## Overhead Compound Pneumatic Planishing Hammer.

The illustration on page 279 is that of an automatic pneumatic hammer, designed

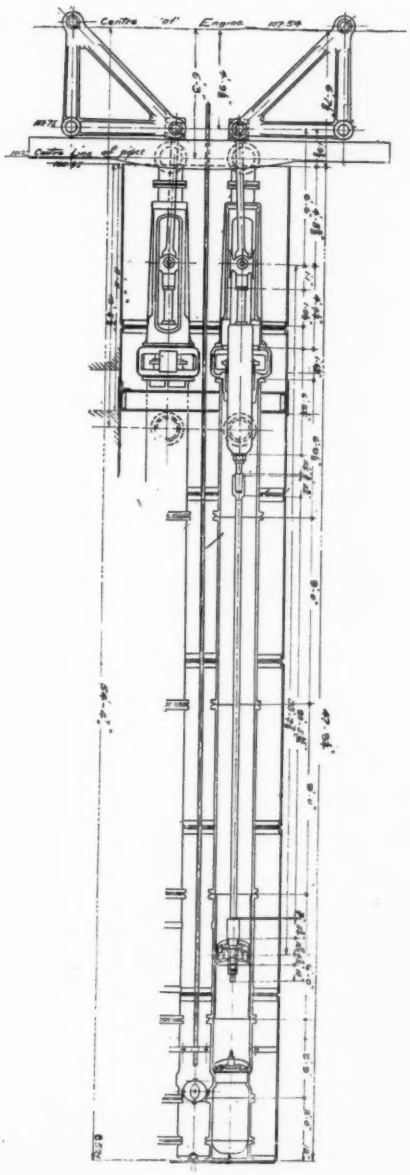


FIG. 3.—ARRANGEMENT OF PLUNGERS AND PUMPS.

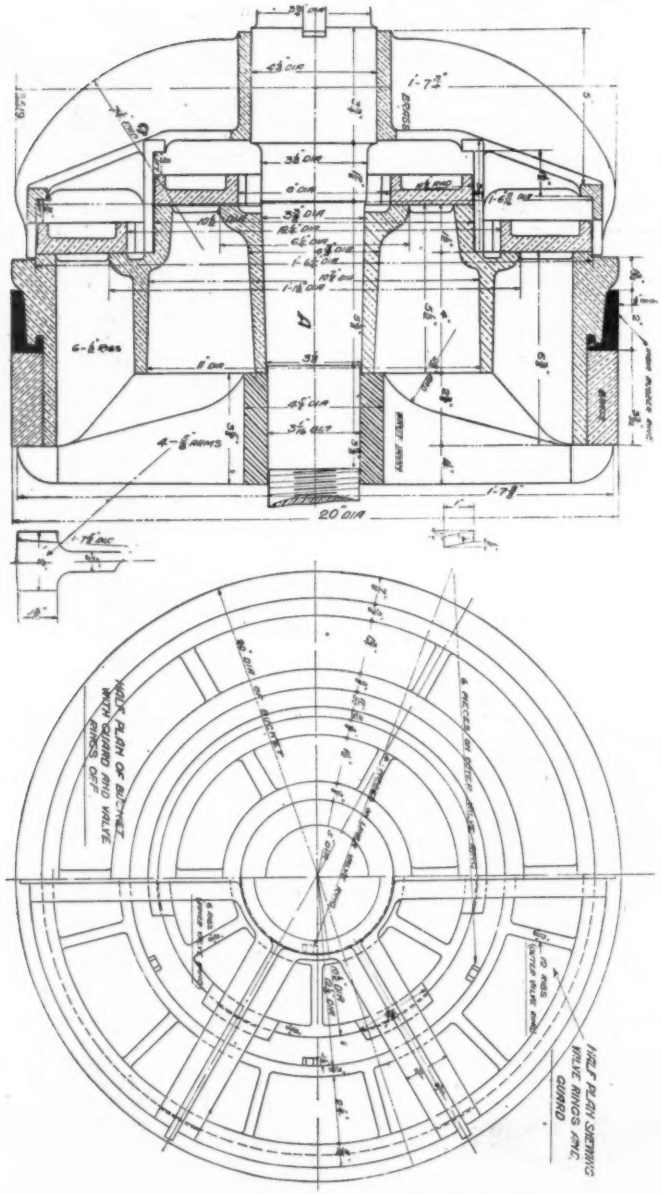
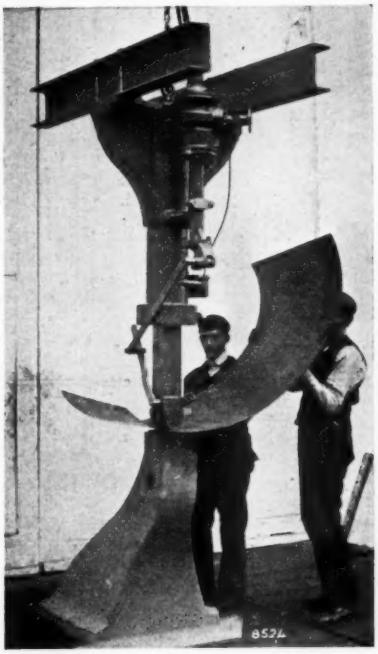



FIG. 4.—PUMPING ENGINE AT KIDDERMINSTER. PUMP DETAILS.

for use in shipyards and boiler shops, for planishing or flue-welding, and is made by Messrs. Peter Pilkington, Ltd., Bamber Bridge, near Preston. It is capable of dealing with copper plates, 13 ft. long, 6 ft. wide, and $\frac{1}{2}$ in. thick, being worked into 42 in. diameter pipe bends. In this type of hammer there are two cylinders, one above the other, the upper one being the working cylinder, the lower one acting as a guide only. The upper end of the tup working in the upper cylinder is built in the shape of a differential piston. Air is admitted in the upper cylinder under the piston for lifting the tup only; and this same air, in exhausting, is expanded on the top side of the piston for striking ordinary blows. When a heavier blow is required, the full air pressure can be utilised on top of the piston. The hammer is self-acting, and can deliver light or heavy blows, continuous or single, at any portion of its stroke, as the operator desires. The air valve as shown in the illustration is connected to the upper cylinder, and is operated by a system of adjustable levers hinged to the valve rod and to the lower part of the tup.




OVERHEAD PNEUMATIC PLANISHING HAMMER

## High Speed Steel Furnace.

Particulars are to hand of a new reverberatory furnace for high speed tool steels which is being introduced by The British Gas Furnace and Tool Co., Ltd., Birmingham.

HIGH SPEED STEEL FURNACE

Its external appearance is shown in the accompanying illustration from which it will be seen that a departure has been made from the usual lines of construction for this class of furnace. The body is circular in shape, the axis lying in a horizontal direction, and the front and back end supports are open so that comparatively long articles may be passed right through. The heating chamber, which is lined with firebrick, is immediately behind the front plate, the latter being made with an inwardly turned central mouth leading into it.

In the heating chamber there are two tangential inlet openings containing gas or oil blowpipe nozzles through which a hot air blast is delivered with the proper proportion of heated gas, or oil spray, to form a gaseous mixture which burns in and around the heating chamber. The arrangement is such that as the heated gaseous mixture is injected into the furnace by the

tangential blowpipes the flame works round and round the heating chamber, forming an annular flame into the interior of which the article to be heated is held.

The gaseous mixture being delivered into the heating chamber under pressure causes a continuous small out-draught at the front and back openings of the furnace so that it is impossible for any free oxygen to enter, and oxidization of the article being heated is therefore prevented.

The back end of the heating chamber is made with an annular recess communicating with waste pipes leading to a regenerative box or chamber made with zigzag passages through which pass the air and gas pipes leading to the blowpipes. When oil fuel is used the air pipes only are so heated.

Both the gas and air supply to the blowpipes are regulated by cocks so that the heat can be regulated to a nicety.

It is stated that a temperature of 2,500° F. can be raised in 20 mins. with an air blast of 2 lbs. per sq. in.

## A Substitute for Platinum in Incandescent Lamps.

As is generally known, platinum enters into the construction of electric incandescent lamps in which it is used to form the connection through the glass with the carbon or metallic filament inside. Its use is based upon the fact that the coefficient of expansion of platinum approximates closely to that of glass, hence it is possible to pass a conductor of this metal through the glass casing of the lamp in such a way as to preserve a vacuum. The high price of platinum has led to many endeavours to discover some cheaper alloy which would prove an efficient substitute, so far without success. What would, however, appear to be a method of much promise, is that recently introduced by Mr. Geo. Calvert. In this, flattened copper wire of No. 27 S. W. G. is employed, that portion at the seal being covered by an enamel in such a fashion as to enable the wire to be hermetically sealed in the lamp without oxidisation taking place. The process of enamelling these strips is a simple one and involves the employment of juvenile labour only.

A life test conducted with 30 lamps fitted with these leading-in wires, we are informed, gave very satisfactory results. The lamps were arranged in two separate groups of 15 each, and connected with a time switch, so that each group was alternately lit for 10 minutes and out for 10 minutes, long enough for the seals to get thoroughly hot, and then thoroughly cold. This run was continued for 500 hours; then the time switch was disconnected, and the lamps were given a continuous run for a further 1,000 hours. During this test none of the lamps failed through deterioration of the vacuum. They are stated to have been in use intermittently for an additional 500 hours, making an actual burning "life" of about 1,750 hours; and after this long period there has been surprisingly little blackening of the bulbs, several of them looking practically as good as new.

The strips which have received the trade name of "Sineplat" are being exploited by a company known as "Platinum Substitutes, Ltd.," who have established a factory, and are already turning out a large number of strips weekly.

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## FIFTH WORKSHOP PRACTICE PRIZE COMPETITION.

### Award of Prizes.

THE four prizes offered for the fifth competition, which closed on March 15th last have been awarded as follows:—

**PRIZE OF £4.**

MR. JOHN J. CLARK,
Shettleston, Glasgow.

**PRIZE OF £1** to each of the following:—MR. R. T. STRONG, Spencer Road, Coventry; MR. S. LAURENCE, Salford, Manchester; and MR. F. BALL, Westoe, South Shields.

The prize articles will be printed in the next issue.

## SIXTH COMPETITION.

We again offer four prizes—one of £4 and three of £1—for the best short article describing and illustrating any emergency device or job that has taxed the ingenuity of those in charge of machine tools, or who are engaged in fitting or erecting. For instructions and conditions see page 212 of the last issue. All articles should be addressed to the Editor of THE ENGINEERING REVIEW, 104, High Holborn, W.C., and marked on the outside "Competition," and the same must be received not later than June 15th.

In this section is presented every month a list of the more important articles appearing in the Engineering Press and of the leading papers read before the various engineering institutions. Full names, addresses, and published prices of the publications indexed are printed each half-year in the volume index.

## Civil Engineering.

Blyth Harbour Improvements. *Engineer, 6th March*, 1908.

Some Lessons from a Cofferdam. *Engineering Record, 29th February*, 1908.

Notes on the Erection of Bridges, IX. *The Railway Engineer, March*, 1908.

Reinforced Concrete Leading Jetty on the Manchester Ship Canal. *Concrete and Constructional Engineering, March*, 1908.

Reinforced Concrete in Reservoir, Aqueduct and Conduit Construction. By E. R. Matthews. *Concrete and Constructional Engineering, March*, 1908.

The Royal Commission on Canals and Waterways, X. *Engineer, 21st February*, 1908.

The Raising of the Assuan Dam. *Engineer, 21st February*, 1908.

The New Roof of Charing Cross Station. *Engineering, 21st February*, 1908.

Structural Steelwork, II. By E. G. Beck. *Mechanical World, 14th* and *28th February*, 1908.

System of Natural Transportation. Transportation by Water. *Practical Engineer, 14th February*, 1908.

The New York Rapid-Transit Subway. By Wm. Barclay Parsons. *Transactions Institution Civil Engineers, 18th February;* Discussion, *25th February*, 1908.

Experimental Determination of Stresses in Web Plates and Stiffeners in Plate Girders. By F. E. Turneaure. *Journal Western Society Engineers, December*, 1907.

The Culebra Cut of the Panama Canal. *Journal Western Society Engineers, December*, 1907.

Les Tunnels Sous-marins de New York (*continued*). *Le Génie Civil, 29th February* and *7th March*, 1908.

## Building.

Concrete Shop Construction with Separately Moulded Members. *Engineering Record, 29th February*, 1908.

The New Open-Hearth Furnace Building, Pennsylvania Steel Works. *Engineering Record, 29th February*, 1908.

The Use of Reinforced Concrete in Engineering and Architectural Construction in America. By E. R. Matthews. *Transactions Society of Arts, 11th March*, 1908.

Reinforced Concrete for Post Office Buildings. *Concrete and Constructional Engineering, March*, 1908.

The Treatment of Concrete Surfaces. By E. B. Green. *Engineering Record, 22nd February*, 1908.

## Heating and Ventilation.

Development of the Fan Blower. *Engineer Chicago, 15th February*, 1908.

## Materials and Measurements.

Tension Tests of Steel Angles with Various Types of End-Connection. *Technology Quarterly, December*, 1907.

Reinforced Concrete from the Contractor's Standpoint. *Engineering Record, 8th February*, 1908.

Refractory Materials. By Thos. Holgate. *Engineering, 21st February*, 1908.

Iron Portland Cement. *Times Engineering Supplement, 26th February*, 1908.

Détermination graphique des efforts réels dans les poutres et hourdis en béton armé. *Le Génie Civil, 7th March*, 1908.

## Boilers, Furnaces, and Fuels.

The Progress of Blast-Furnace Gas Utilisation. *Western Electrician, 1st February*, 1908.

The Strength of Steam Boilers. *Engineer, Chicago, 15th February*, 1908.

A New Rotary Kiln Cement Plant. *Engineer, 28th February*, 1908.

Advantages of Corrugated Flues. By Vernon Smith. *Practical Engineer, 21st February*, 1908.

Steam Boilers (*continued*). *Practical Engineer, 28th February*, 1908.

Smoke Density Determination. A New Method and How to Record Readings. By E. J. Kunze. *Engineer, Chicago, 1st February*, 1908.

## Engines and Motors.

Siegen-Körting Gas Engines. *Iron and Coal Trades Review, 6th March*, 1908.

The Manufacture of Small Steam Turbines. *Machinery, February*, 1908.

The Question of Steam Turbine Safety Governors, I. *Practical Engineer, 6th March*, 1908.

The Testing of Gas Engines. By Gilbert Whalley. *Journal Gas Lighting, &c., 25th February*, 1908.

Proportion of Parts of Triple-Expansion Engines. Advantages of the Triple-Expansion Engine for Marine Work and Detail of Construction. *Engineer, Chicago, 1st February*, 1908.

Design of a 400-k.w. Reaction Turbine. Number of Stages and Blades in each Expansion and Principal Dimensions By H. F. Schmidt. *Engineer, Chicago, 1st February*, 1908.

Steam Turbine Construction, V. By T. Franklin. *Mechanical World, 21st February*, 1908.

## Hydraulics and Compressed Air.

Notes on Centrifugal Pumps, VII. *Mechanical World, 6th March*, 1908.

Methods of Pumping Deep Ground Waters. *Journal Western Society Engineers, December*, 1907.

## Shop Equipment and Practice.

Making Thread Gauges. *Machinery, February*, 1908.

Machining a Milling Machine Spindle and Parts (*continued*). By G. H. Gibbs. *Mechanical World, 28th February*, 1908.

Notes on Mill Power Plant, XVIII. By C. J. Kavanagh. *Mechanical World, 28th February*, 1908.

## Miscellaneous Mechanical Subjects.

The Mechanical Engineering of Collieries (*continued*). By T. Campbell Futers. *Colliery Guardian, 14th, 21st* and *28th February*, and *6th March*, 1908.

A New Coal Hoist at Leith. *Engineer, 6th March*, 1908.

Notes on the Use of Grinding Machines. By J. E. Livermore. *Engineering, 6th March*, 1908.

Gear-Cutting Machinery, II. *Machinery, February*, 1908.

Screw Thread Systems. *Machinery, February*, 1908.

Laying out Cams for Rapid Motion. *Machinery, February*, 1908.

The Action of Toothless Circular Saws. By F. W. Harbord. *Engineer, 21st February*, 1908.

Turning Gear for Swing Bridge over the River Hull at Sculcoates. *Engineering, 21st February*, 1908.

Notes on Boat and Anchor Cranes (*continued*). *Mechanical World, 14th February*, 1908.

## Locomotive and Railway Engineering.

The Iron Sleeper. *Engineer, 28th February* and *6th March*, 1908.

Locomotive Smoke Stacks. *American Engineer and Railroad Journal, March*, 1908.

Steel Passenger Equipment (*continued*). *American Engineer and Railroad Journal, March*, 1908.

Lateral Thrust of Car Wheels on Curves. *Railway and Engineering Review, 29th February*, 1908.

Power Reversing Gear. Great Eastern Railway. *Railway Engineer, March*, 1908.

Locomotive Journals and Bearings, II. *Railway Engineer, March*, 1908.

Crewe, London and North Western Railway. *Railway Engineer, March*, 1908.

The Problem of Track Support. *Railway and Engineering Review, 22nd February*, 1908.

A Modern French Locomotive Boiler. *Railway Gazette, 6th March*, 1908.

Large Railway Stations, II. *Engineer, 28th February*, 1908.

Crane Locomotive for the Buenos Ayres and Rosario Railway Co. *Engineering, 21st February*, 1908.

Locomotive Feed Water Heater, Central of Georgia Railway. *American Engineer and Railroad Journal, February*, 1908.

Building Wooden Freight Cars, Canadian-Pacific Railway. *American Engineer and Railroad Journal, February*, 1908.

Rack Locomotive for the Villa Nova de Gaya Railway, Portugal. *Engineering, 14th February*, 1908.

The Shelling Out of Steel Wheels and Tyres. *Railway Gazette, 14th February*, 1908.

Indian Railway Wagon Construction: Broad Gauge Wagons (5 ft. 6 in. gauge). *Railway News, 22nd February*, 1908.

The Break of Gauge Problem. *Railway News, 22nd February*, 1908.

South American Trans-Continental Railways. *Times Engineering Supplement, 19th February*, 1908.

## Motor Engineering.

A Number of Things: And their Effect on Tyres. By M. O'Gorman. *Automobile Club Journal, 5th March*, 1908; *Automotor Journal, 7th March*, 1908.

Military Transport Wagon. *Engineer, 28th February*, 1908.

Inland Motor Boating. *Automotor Journal, 29th February* and *7th March*, 1908.

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## Stability of Holborn Viaduct.

At a recent meeting of the Court of Common Council of the City of London, Mr. Deputy Millar Wilkinson asked the Chairman of the Streets Committees whether his attention had been called to a statement in the Engineering Press, adverting upon reports as to the stability of Holborn Viaduct, and whether he had any information to give the Court of a reassuring character on the matter?

Mr. G. H. Heilbuth, Chairman of the Committee, stated in reply, that on 2nd March the City engineer examined the bridge over the Viaduct, and could find no movement. A subsequent examination confirmed the opinion that no variation had taken place in the cracks, or the slight displacement of the capstone, as shown in figures taken in 1897, and the stability of the structure was in no way affected.